PB81-165508

Evaluation of Fugitive Dust Emissions from Mining

PEDCo-Environmental, Inc.
Cincinnati, OH

Prepared for

Industrial Environmental Research Lab.
Cincinnati, OH

1980

U.S. Department of Commerce
National Technical Information Service
NTIS

PB81-165508

DRAFT

EVALUATION OF FUGITIVE DUST EMISSIONS FROM MINING

by

George Jutze
Kenneth Axetell
Robert Amick
PEDCo Environmental, Inc.
Cincinnati, Ohio 45246

Contract Nos. 68-02-1321, Task No. 36,
and 600/9-76-001

EPA Project Officer

S. J. Hubbard
Resource Extraction and Handling Division
Industrial Environmental Research Laboratory
Cincinnati, Ohio 45268

INDUSTRIAL ENVIRONMENTAL RESEARCH LABORATORY
OFFICE OF RESEARCH AND DEVELOPMENT
U.S. ENVIRONMENTAL PROTECTION AGENCY
CINCINNATI, OHIO 45268

REPRODUCED BY
NATIONAL TECHNICAL
INFORMATION SERVICE
U.S. DEPARTMENT OF COMMERCE
SPRINGFIELD, VA 22161

DISCLAIMER

This report has been reviewed by the Industrial Environmental Research Laboratory, U.S. Environmental Protection Agency, and approved for publication. Approval does not signify that the contents necessarily reflect the views and policies of the U.S. Environmental Protection Agency, nor does mention of trade names or commercial products constitute endorsement or recommendation for use.

ABSTRACT

This evaluation of fugitive dust air pollution from mining operations identifies and compiles currently available information on emission sources and rates, regulatory approaches, control techniques, measuring and monitoring techniques, health and welfare effects, and research programs related to mining activities. The assembled information serves as a basis for the design of near-term research and development programs that might be implemented by the Environmental Protection Agency.

The scope of the study includes both surface and underground mining plus related operations normally performed at the mine sites, such as crushing and storage. Nearly all particulate emissions at mines are categorized as fugitive dust because they generally are emitted at ground level as a result of equipment activity or material transfer rather than from stacks.

CONTENTS

Page

Abstract iii

List of Figures v

List of Tables vi

1. Introduction 1

2 Identification of Fugitive Dust Sources Associated with Mining Activities 3

3 Regulatory Policies 71

4 Control Methods 84

5 Measuring and Monitoring Techniques 95

6 Health and Welfare Effects 105

7 Research and Development Programs 108

8 Recommendations Regarding Additional Research and Development 113

LIST OF FIGURES

Figure Page

1 Locations of Largest U.S. Coal Mines 6

2 Locations of Largest U.S. Copper Mines 9

3 Production of Crushed Rock by State, Percent 11

4 Locations of Largest U.S. Phospate Rock Mines 14

5 Overburden Removal 21

6 Dust Plume from Blasting Operations 27

7 Truck Loading 30

8 Large Capacity Truck on a Well-Controlled Haul Road 35

9 Truck Dumping 39

10 Crushing 42

11 Transfer and Conveying 45

12 Storage 50

13 Waste Disposal 55

14 Reclamation 60

15 Climatic Factors for Use in the Wind Erosion Equation 63

16 Overhead View of Dust Plume from Moving Point Source 98

17 MRI Vertical Profiler 101

18 Format for Scheduling Reclamation Operations 115

LIST OF TABLES

Table		Page
1	Largest U.S. Coal Mines	5
2	Largest U.S. Copper Mines	8
3	Largest U.S. Phosphate Mines	13
4	Dust-Producing Operations by Mining Industry	16
5	Emission Factors for Crushed Rock Storage Piles	52
6	Summary of Emission Factors for Mining Operations	65
7	Summary of State Ambient Air Quality Standards and Fugitive Dust Regulations	74
8	Summary of Control Efficiencies and Costs for Mining Fugitive Dust Sources	92

SECTION 1

INTRODUCTION

This evaluation of fugitive dust air pollution from mining operations identities and compiles currently available information on emission sources and rates, regulatory approaches, control techniques, measuring and monitoring techniques, health and welfare effects, and research programs related to mining activities. The assembled information serves as a basis for the design of near-term research and development programs that might be implemented by the Resource Extraction Handling Division (REHD) of the Industrial Environmental Research Laboratory (IERL)/Cincinnati.

The scope of the study includes both surface and underground mining plus related operations normally performed at the mine sites, such as crushing and storage. It does not include dust that is generated and remains underground or in an enclosed area--only emissions that affect ambient air quality. Neither does it include emissions that occur off-site (during shipping or at distant processing plants). Almost all particulate emissions at mines are categorized as fugitive dust because they generally are emitted at ground level as a result of equipment activity or material transfer rather than from stacks.

Data for this report were obtained from a literature search (including PEDCo's files on fugitive dust sources) and from observations and personal contacts made during study-related field trips. Although not intended to be exhaustive, the literature search was thorough enough to uncover all studies in which fugitive dust emissions from mining operations were quantified by a reasonably accurate procedure. Primary importance was attached to including all mining activities that are major dust sources.

This evaluation includes the following, listed by section number:

2. Identification of fugitive dust sources associated with mining activities and their emission rates.

3. Regulatory policies of Federal, state, and local agencies that directly or indirectly affect the control of fugitive dust from mining sources.

4. State-of-the-art control technologies for each mining fugitive dust source.

5. State-of-the-art techniques and equipment for measuring and monitoring ambient levels of fugitive particulates.

6. Effects of fugitive dust from mining sources on health and welfare.

7. A compilation of ongoing and planned R & D studies related to mining fugitive dust sources.

8. Several suggested potential areas for research and development programs by REHD-IERL/Cincinnati.

SECTION 2

IDENTIFICATION OF FUGITIVE DUST SOURCES ASSOCIATED WITH MINING ACTIVITIES

MAJOR MINING INDUSTRIES

The coal, copper, crushed stone, and phosphate rock industries probably are the four largest nonferrous mineral mine sources of fugitive dust in the nation. This chapter briefly discusses each of those industries to provide a basis for evaluating the extent and impact of fugitive dust air pollution from mining operations.

All four of these minerals are recovered primarily by surface mining, which has far more potential for fugitive dust emissions than underground mining. In addition, the tonnages removed from these mines are generally greater than for other minerals and ores. Other minerals considered (because large tonnages are surface-mined) are iron, oil shale, sand, and gravel. Iron ore mining was eliminated because ferrous metals are not within the purview of the Resource Extraction and Handling Division of the Cincinnati Industrial Environmental Research Laboratory. Oil shale was excluded because no large-scale oil shale surface mines are presently in operation. Sand and gravel mining was eliminated from consideration because much of this material is mined and processed wet, and dust is not a problem.

Mining operations other than the four examples covered here certainly can be major fugitive dust sources. Most have the same unit operations and points of dust release, so their emissions can be estimated by comparison with any one of the four mining industries for which data have been assembled.

Coal Mining

A total of 547.30 million Mg (603.4 million tons) of bituminous coal and lignite was mined in the United States in 1974. This represents the output of 5247 mines, (3208 surface mines and 2039 underground mines). Production from surface mines accounted for 54 percent of the total in 1974, surpassing underground mines in output for the first time.[2]

Table 1 lists the 50 largest coal mines and their 1973 and 1974 production rates. These mines (34 surface and 16 underground) produced 24.6 percent of the coal mined in 1974. Figure 1 shows the locations of these mines. They are concentrated in the coal mining areas of Appalachia, the Central states, the Northern Great Plains, and the Four Corners area. All of the Western mines shown, plus those in Indiana, Ohio, and most of those in Kentucky are surface mines.

Although total coal production has been relatively stable for several years, a definite shift has taken place from the underground mines in the East to the low-sulfur coal strip mines in the West. This trend is expected to accelerate in the future with the opening of giant new mines in Powder River Basin, northwestern Colorado, the Four Corners area, and the lignite fields of North Dakota and eastern Montana. Many of these mines will be used to supply coal gasification plants and mine-mouth power plants.

The most unique aspect of surface coal mining is the huge amount of earth moving associated with it. The overburden removal operations to get to the coal seams dwarf previous major earth moving projects such as canals and dams. A new generation of larger earth moving equipment was developed to handle this task.

Almost all surface mines use trucks to transport the coal from the mine to the processing area or loading ramp. Railroads are the most common means of shipping the coal to consumers (66 percent of the tonnage in 1974). Almost 40 percent of this

Table 1. LARGEST U.S. COAL MINES

Company	Mine	State	Est. Production Mg/yr (10^3 ton/yr)	
			1974	1973
Utah International	Navajo[a]	NM	6308 (6955)	6702 (7389)
Decker	Decker No. 1[a]	MT	6155 (6786)	3772 (4159)
Peabody	River King[a]	Il	5872 (6474)	5919 (6526)
Peabody	River Queen[a,b]	KY	4266 (4703)	3764 (4172)
Southwestern Illinois	Captain[a]	IL	3943 (4347)	4037 (4451)
Peabody	No. 10[b]	IL	3748 (4132)	3761 (4147)
C&K	Fox[a]	PA	3628 (4000)	2376 (2620)
Peabody	Black Mesa[a]	AZ	3567 (3933)	2945 (3247)
Washington Irrigation Dist.	Centralia[a]	WA	3528 (3890)	2929 (3229)
Clinchfield Div., Pittston	Moss No. 3[b]	VA	3337 (3679)	3540 (3903)
Peabody	Sinclair[a]	KY	3201 (3529)	4799 (5291)
Central Ohio	Muskingum[a]	OH	3054 (3367)	3327 (3368)
Amax	Belle Ayr[a]	WY	3005 (3313)	814 (898)
Consolidation, Central Division	Egypt Valley[a]	OH	2950 (3253)	3861 (4257)
Peabody	Lynnville[a]	IN	2931 (3232)	3687 (4065)
Western Energy	Colstrip[a]	MT	2914 (3213)	3858 (4254)
Arch Minerals	Seminoe No. 1[a]	WY	2850 (3142)	2599 (3865)
Amax	Leahy[a]	IL	2570 (2834)	2668 (2942)
Peabody	Universal[a]	IN	2570 (2833)	2761 (3044)
U.S. Steel	Robena	PA	2553 (2815)	2604 (2871)
Peabody	Ken[a,b]	KY	2533 (2693)	2904 (3202)
Pacific Power & Light	Dave Johnston[a]	WY	2437 (2687)	2628 (2897)
Amax	Ayrgem[a]	KY	2435 (2685)	2908 (3206)
Arch Minerals	Seminoe No. 2[a]	WY	2349 (2590)	1359 (1498)
Peabody	Camp No. 1[b]	KY	2293 (2528)	2376 (2620)
Peabody	Kayenta[a]	AZ	2281 (2515)	-- --
Monterey	No. 1	IL	2249 (2480)	2444 (2695)
Inland Steel	Inland	IL	2239 (2469)	2347 (2588)
Kemmerer	Sorensen[a]	WY	2210 (2436)	2209 (2546)
Amax	Ayrshire[a]	IN	2180 (2404	250 (227)
Consolidation, Mountaineer Div.	Robinson Run[b]	WV	2159 (2380)	2178 (2401)
Old Ben	Old Ben No. 1[a]	IN	2127 (2345)	2173 (2396)
Peabody	Big Sky[a]	MT	2022 (2229)	1689 (1972)
Peabody	Homestead[a]	KY	1990 (2194)	2221 (2449)
Island Creek	Pevler No. 1[a,b]	KY	1985 (2189)	1572 (1733)
Consolidation, Christopher Div.	Humphrey No. 7[b]	WV	1955 (2155)	2442 (2692)
Consolidation, Mountaineer Div.	Loveridge[b]	WV	1800 (1985)	1982 (2185)
Rosebud	Rosebud[a]	WY	1680 (1963)	1370 (1510)
Old Ben	No. 24[b]	IL	1778 (1960)	2156 (2377)
Freeman	Orient No. 3[b]	IL	1741 (1919)	2002 (2207)
Consolidation, Ohio Valley Div.	Ireland[b]	WV	1687 (1860)	2125 (2343)
Peabody	Vogue[a]	KY	1645 (1814)	2188 (2412)
Mathies	Mathies[b]	PA	1641 (1809)	1847 (2036)
Peabody	Star[b]	KY	1640 (1808)	1813 (1999)
Amax	Wright[a]	IN	1624 (1790)	1902 (2097)
Amax	Minnehaha[a]	IN	1624 (1790)	1825 (2012)
Mountain Drive	Mountain Drive[a]	KY	1601 (1765)	1508 (1663)
Old Ben	No. 26[b]	IL	1577 (1739)	1905 (2100)
Peabody	Baldwin[b]	IL	1566 (1727)	1905 (2100)
Knife River	Beulah[a]	ND	1562 (1722)	1565 (1726)

[a] Strip mines

[b] Underground mines

Source: Bituminous Coal Data, 1974 Edition, National Coal Association, Washington, D.C., 1975.

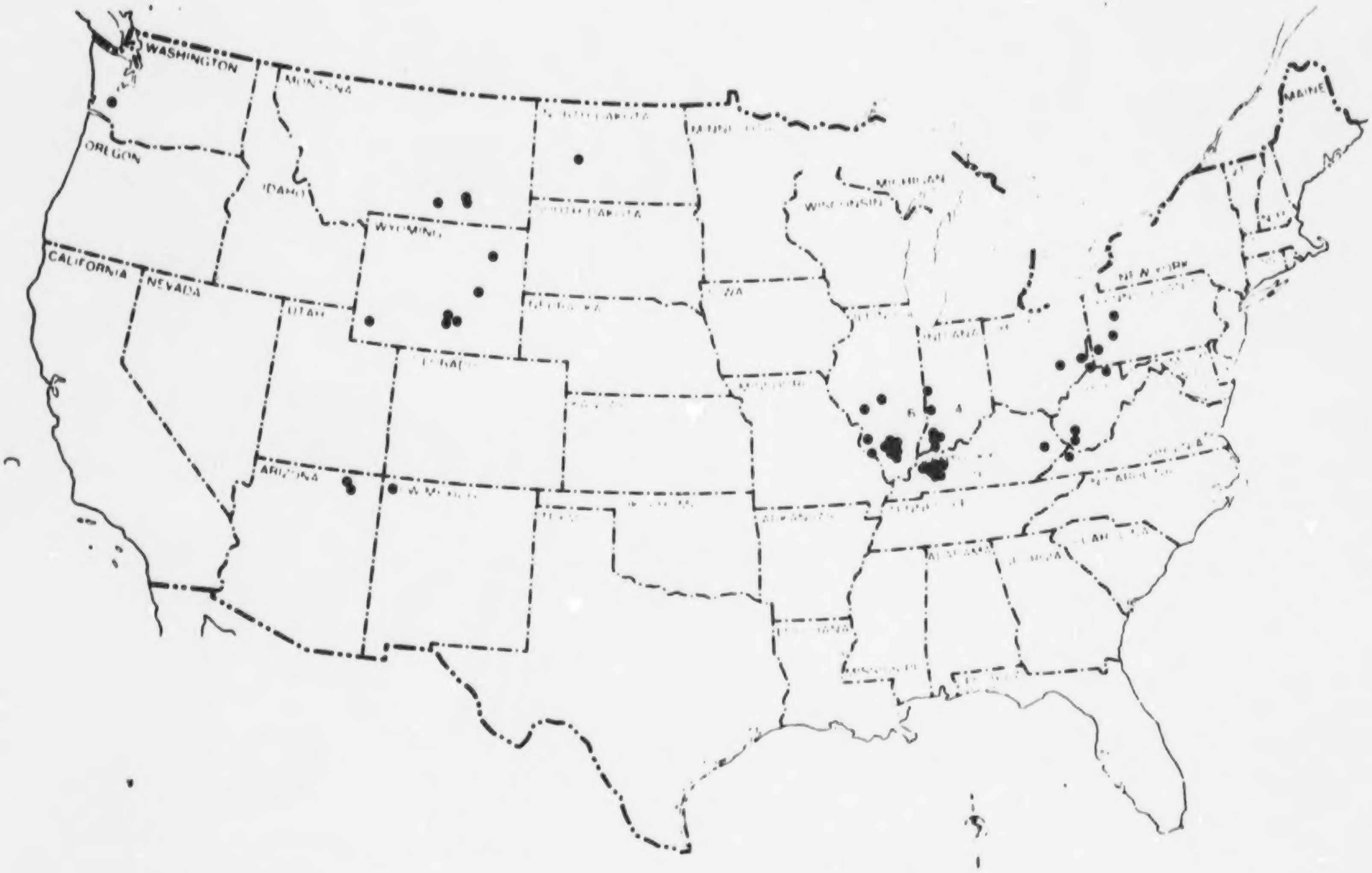

WASHINGTON
OREGON
CALIFORNIA
NEVADA
IDAHO
MONTANA
WYOMING
UTAH
ARIZONA
NEBRASKA
WISCONSIN
MICHIGAN
NEW YORK
MAINE

Figure 1. Locations of largest U.S. coal mines.

amount was transported in unit trains. Barges, trucks, and mine-mouth operations account for the remainder of the tonnage distributed (with 11 percent each). All other modes of transportation together account for less than 1 percent.[2]

Copper Mining

Domestic mine production of recoverable copper in 1975 was 1.28 million Mg (1.41 million tons), down sharply from the 1.45 million Mg (1.60 million tons in 1974) and 1.56 million Mg (1.72 million tons) in 1973, as a result of decreased demand for copper products. The principal copper-producing states were Arizona (56.6% of the total), Utah (12.7%), New Mexico (10.4%), Montana (7.2%), Nevada (5.6%), and Michigan (5.2%).[3] Table 2 lists the largest 25 copper mines, which provided 89 percent of the total production in 1973. Figure 2 shows the locations of these mines.

Open-pit mines accounted for 83 percent of mine output and underground mines for 16 percent. The production of copper from leach pads and in-place leaching (mainly recovvered by precipitation with iron) was 145,000 million Mg (160,000) tons in 1973, or 9 percent of the output from the mines.[3]

As indicated from the above data, copper mining is characterized by very large mines of relatively low-grade ore rather than many small mines in rich veins. (The material average yield of copper in copper ore was only 0.53 percent). This low-grade ore necessitates the handling of large quantities of material in the mining and processing steps. Also, wide variations in copper content within the ore body can require the mining and handling of additional amounts of waste material that is too low in copper content to justify recovery.

Approximately 94 percent of the ore is concentrated before it is smelted. The concentration (by froth flotation) usually occurs at the mine site because this reduces the amount of material that must be shipped to the smelter. The smelters are located in proximity to the major ore deposits and most of the concentrated ore is shipped via unit trains on the copper

Table 2. LARGEST U.S. COPPER MINES

Company/Mine	Estimated production,		State	County
	Mg	(tons)		
Kennecott Copper Utah Copper	231,000	(225,000)	UT	Salt Lake
Magma Copper San Manuel	143,600	(158,300)[a]	AZ	Pinal
Phelps Dodge Morenci	108,400	(119,500)	AZ	Cochise
Anaconda Berkeley Pit	115,900	(127,800)[a]	MT	Silver Bow
Phelps Dodge Tyrone	94,000	(104,000)	NM	Grant
Kennecott Copper Ray Pit	89,700	(98,900)	AZ	Pinal
Cyprus Mines Pima	79,900	(88,100)	AZ	Pima
White Pine Copper White Pine	69,500	(76,600)	MI	Ontonagon
Duval Sierrita Sierrita	NA	NA	AZ	Pima
Kennecott Copper Chino	614,500	(67,800)	NM	Grant
Anamax Mining Twin Buttes	66,800	(73,600)	AZ	Pima
Phelps Dodge New Cornelia	48,800	(53,800)	AZ	Pima
Inspiration Copper Inspiration	39,100	(43,100)	AZ	Gila
Asarco Mission	42,300	(46,600)	AZ	Pima
Kennecott Copper Ruth	45,000	(50,000)	NV	White Pine
Anaconda Yerington	32,500	(35,800)	NV	Lyon
Asarco Silver Bell	21,600	(23,800)	AZ	Pima
Anaconda Butte Hill	NA	NA	MT	Silver Bow
Cities Service Copper Cities	NA	NA	AZ	Gila
Duval Mineral Park	NA	NA	AZ	Mohave
Magma Copper Magma	NA	NA	AZ	Pinal
Phelps Dodge Copper Queen	NA	NA	AZ	Cochise
UV Industries Continental	NA	NA	NM	Grant
Bagdad Copper Bagdad	NA	NA	AZ	Yavapai
Duval Esperanza	NA	NA	AZ	Pima

[a] This figure includes underground as well as open-pit production.
NA = not available

Source: Preprint from the 1973 Bureau of Mines Minerals Yearbook, Copper, U.S. Department of the Interior, Bureau of Mines, Washington, D.C., 1973, pp. 2-5.

Source: Fugitive Dust from Mining Operations, Monsanto Research Corporation, Dayton, Ohio, prepared for U.S. Environmental Protection Agency, 1975.

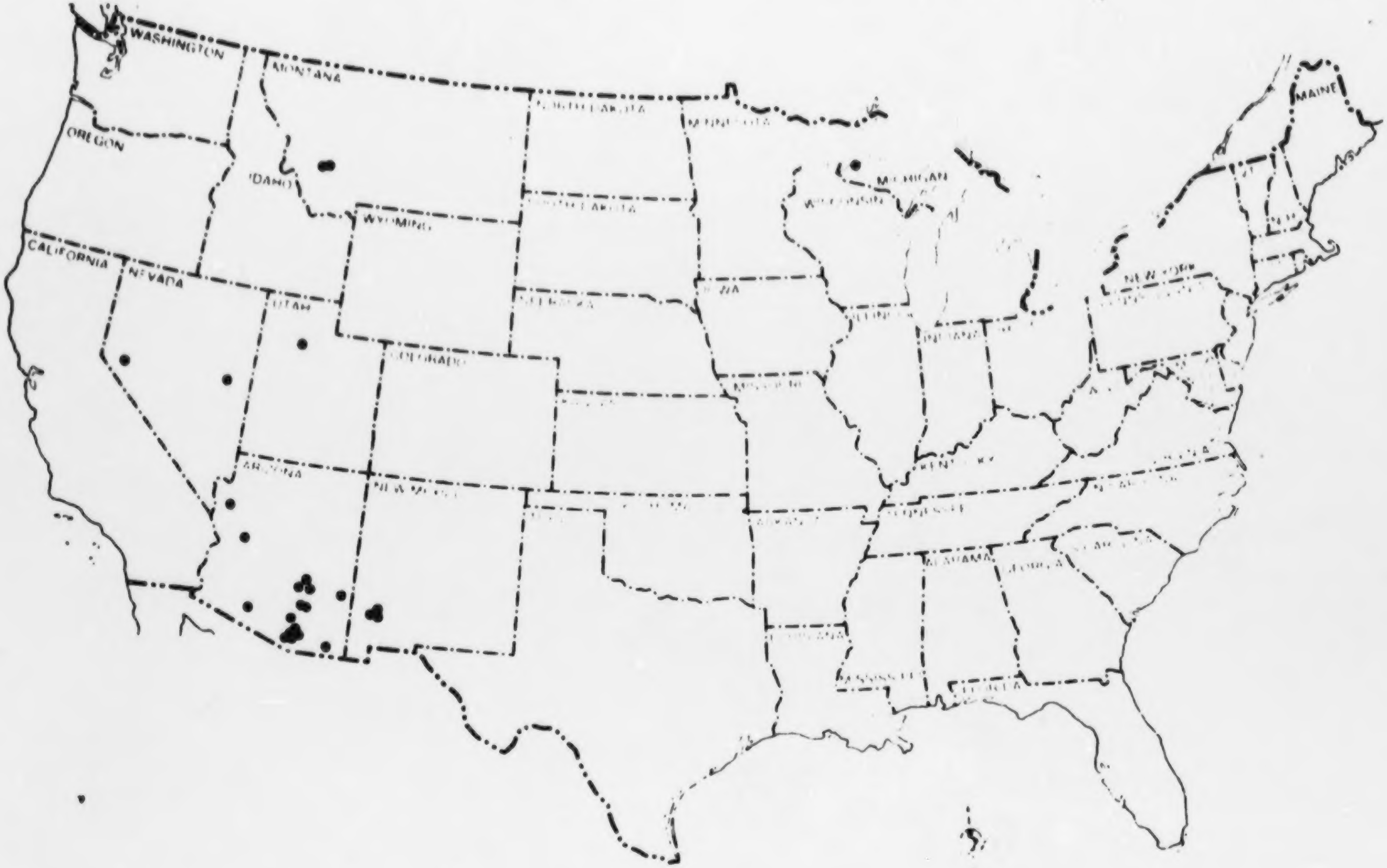

WASHINGTON
MONTANA
OREGON
IDAHO
CALIFORNIA
NEVADA
UTAH
WYOMING
COLORADO
ARIZONA
NEW MEXICO
NORTH DAKOTA
SOUTH DAKOTA
MINNESOTA
WISCONSIN
MICHIGAN
NEBRASKA
IOWA
MISSOURI
ILLINOIS
INDIANA
KENTUCKY
TENNESSEE
ALABAMA
GEORGIA
MISSISSIPPI
LOUISIANA
NEW YORK
MAINE

Figure 2. Locations of largest U.S. copper mines.

companies' private tracks. Smaller mining companies that do not have their own smelters send their ore to custom smelters. This usually involves longer shipping distances.

Stone Quarrying

Stone production in 1974 totaled 94.7 million Mg (1.044 billion tons). Of this amount, 94.5 million Mg (1.042 billion tons) was crushed stone.[4] Crushed stone was produced in every state except Delaware, with Florida, Illinois, Missouri, Ohio, Pennsylvania, and Texas accounting for more than one-third of the national total. Figure 3 shows the percentage of total crushed rock quarried in each state with significant production.

Active quarries in the country numbered 5431 in 1974. Of these, 228 mined at least 820,000 Mg (900,000 tons) during the year and accounted for 37 percent of the domestic production.[4] Stone quarrying tends to be an industry of smaller operations serving local and regional needs. Almost all stone quarries are open-pit mines.

Blasting is normally used in quarrying crushed rock; other equipment, such as rippers and hydraulic excavators, may be used to break the rock loose.

Most of the crushed rock is used for construction-related purposes such as roadbases, concrete aggregate, or cement manufacture. In many cases, pits or quarries may be operated in conjunction with specific construction projects and mined only intermittently. The crushing plants are often portable and may be used to service as many as 10 different quarries.

It is desirable to have quarries located close to the usage points of the stone; therefore they are more likely to be in or near populated areas than are other types of mines. This proximity causes greater concern about the environmental impacts of quarries than of the more remote mines--noise, dust, truck traffic, blasting, and inadequate site reclamation after mining have all created local problems.

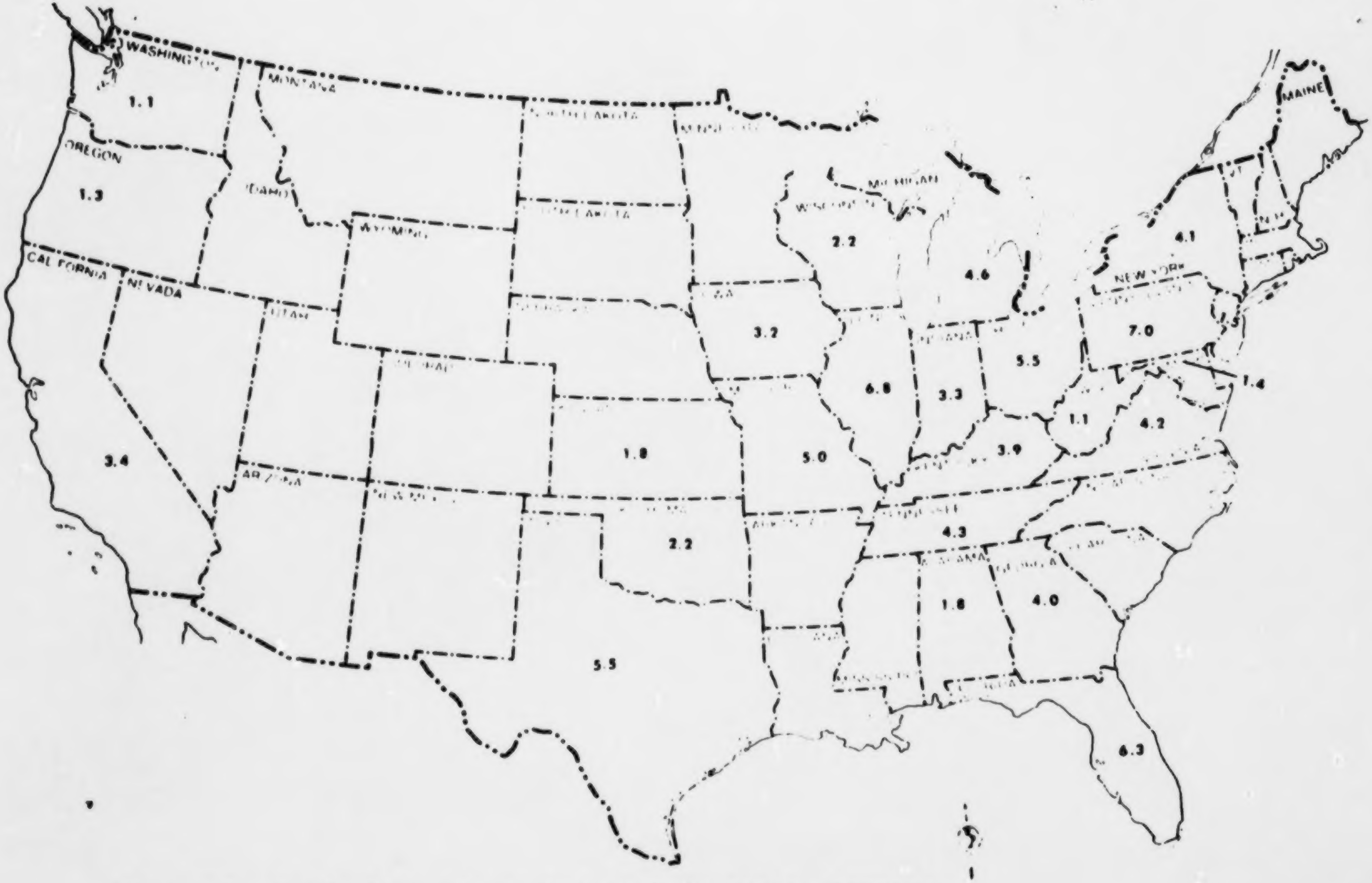

WASHINGTON
1.1
MONTANA
OREGON
1.3
IDAHO
WYOMING
CALIFORNIA
NEVADA
UTAH
3.4
ARIZONA
1.8
2.2
5.5
3.2
5.0
MICHIGAN
2.2
4.6
6.8
3.3
5.5
3.9
4.3
1.8
4.0
6.3
1.1
4.2
7.0
NEW YORK
4.1
1.4
VT
N.H.
MAINE
TENNESSEE
ALABAMA
GEORGIA

Figure 3. Production of crushed rock by state, percent.

Phosphate Rock Mining

Marketable phosphate rock production in 1975 was 44.3 million Mg (48.8 million tons), an increase from the 41.4 million Mg (45.7 million tons) of 1974 and 38.2 million Mg (42.1 million tons) of 1973. Mining of phosphate rock is concentrated in Florida, which accounted for 77.7 percent of the total national output in 1975. Much of the Florida phosphate rock is mined in Polk County in west central Florida. Figure 4 shows locations of the 24 largest mines, and Table 3 lists their estimated production rates. These 24 mines accounted for 77 percent of phosphate rock mined in 1975.[5]

Mining procedures differ somewhat according to the different types of phosphate rock deposits found in Florida, Tennessee, and the Western states. The Florida land pebble deposits are contained in a matrix of sandy clay averaging 5 m (16 ft) in thickness, overlain by a 6 m (20 ft) overburden of sandy soil.[6] Before mining, the land is drained and vegetation is removed. Draglines with 27 to 42 m^3 (35 to 55 cubic yd) buckets strip the overburden and mine the matrix simultaneously. The overburden is dumped into an adjacent mined-out area or stacked on natural ground adjacent to the cut. The matrix is deposited in a previously prepared sluice pit where it is slurried by hydraulic guns. The slurry is pumped for distances up to 10 km (6 miles) to a washing plant.

Phosphate rock ore in Tennessee is stripped and mined from consolidated deposits with 1 to 2 m^3 (2 to 3 cubic yd) draglines, then trucked to the processing plant.

All phosphate ore in the Western states is strip-mined except that produced by two underground mines in Montana. In southeastern Idaho, the mines use scrapers, bulldozers, or power shovels to remove overburden and mine the ore. In Utah, phosphate is quarried after an overlying limestone layer is drilled, blasted, and removed. In all of these states the mined ore is transported to processing plants either by truck or by rail.

Table 3. LARGEST U.S. PHOSPHATE MINES

Company/Mine	Estimated production, 10^6 Mg	$(10^6$ ton/yr)	State	County
IMC Clear Springs Noralyn Homeland Phosphoria Achan Kingsford	10.0	(11.0)	FL	Polk
Agrico Palmetto Payne Creek Saddle Creek Fort Green	6.3	(7.0)	FL	Polk
Mobil				
Fort Mead	3.0	(3.3)	FL	Polk
Nichols	1.1	(1.2)		Polk
Occidental Suwannee	3.2	(3.5)[a]	FL	Hamilton
Swift Silver City Watson	2.4	(2.6)	FL	Polk
W. R. Grace Bonny Lake	2.3	(2.5)	FL	Polk
Brewster Haynsworth	1.6	(1.8)	FL	Polk
Gardinier Fort Meade	1.6	(1.8)	FL	Polk
USS-AgriChemicals Rockland Lake Hancock	1.1	(1.2)	FL	Polk
Texasgulf Lee Creek	0.5	(0.5)[a]	NC	Beaufort
Borden Tenoroc	0.4	(0.4)	FL	Hillsborough
Beker Manatee	0.4	(0.4)	FL	Manatee
Stauffer Vernal	0.4	(0.4)[a]	UT	Uintah

[a] This figure is from 1973 data, preprint of the 1973 Bureau of Mines Minerals Yearbook, Phosphate Rock, pp. 3-5.

Source: Particulate and Sulfur Dioxide Area Source Emission Inventory for Duval, Hillsborough, Pinellas, and Polk Counties, Florida, PEDCo Environmental, Inc., Cincinnati, Ohio. Prepared for U.S. Environmental Protection Agency. June 1975.

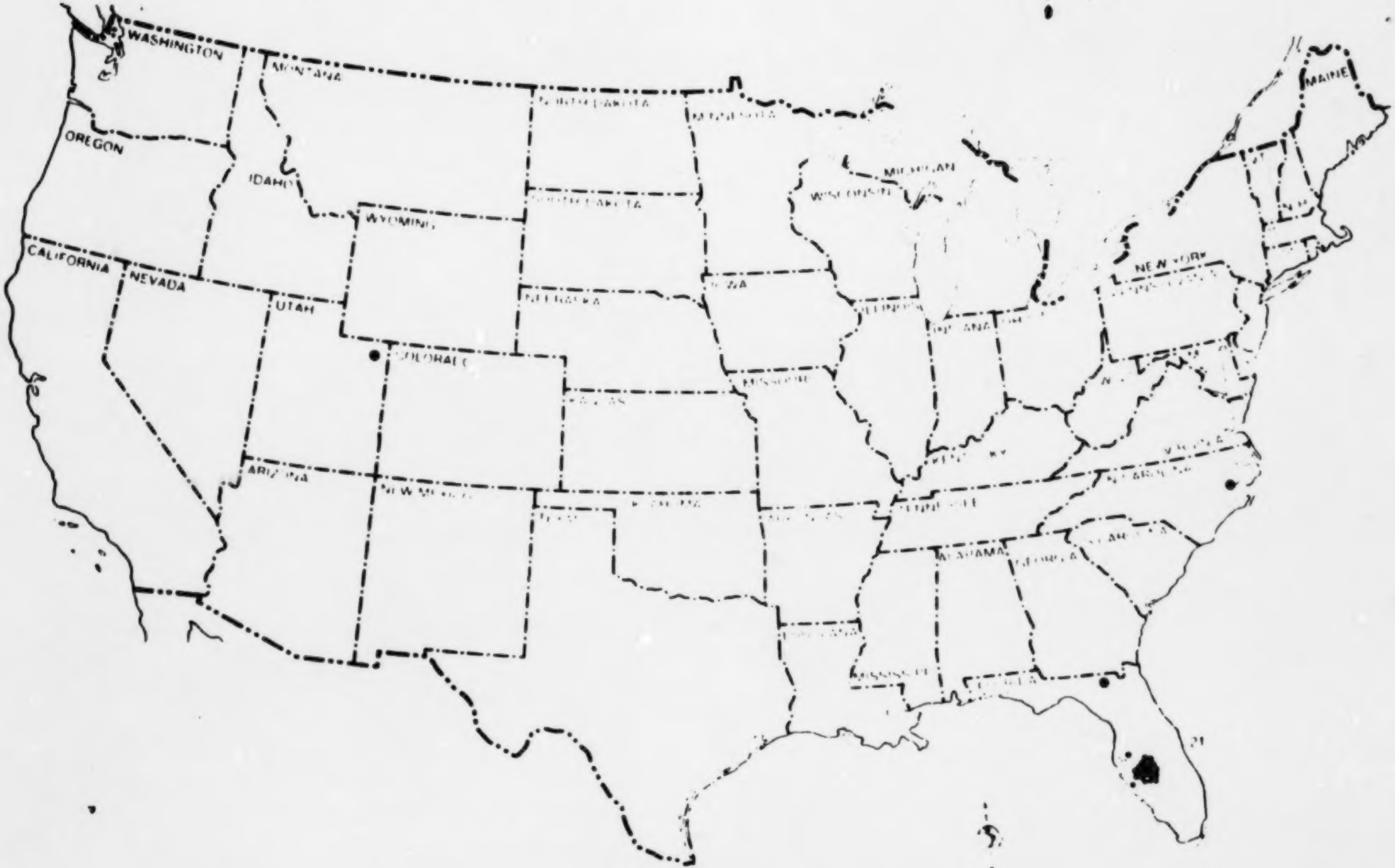

WASHINGTON
OREGON
CALIFORNIA
NEVADA
IDAHO
MONTANA
WYOMING
UTAH
COLORADO
ARIZONA
NEW MEXICO
NORTH DAKOTA
SOUTH DAKOTA
NEBRASKA
KANSAS
MINNESOTA
IOWA
MISSOURI
WISCONSIN
MICHIGAN
ILLINOIS
INDIANA
KENTUCKY
TENNESSEE
ALABAMA
GEORGIA
NEW YORK
MAINE

Figure 4. Locations of largest U.S. phosphate rock mines.

From 1971 to 1975, worldwide demand for phosphate rock exceeded production capacity, reversing a condition of oversupply that had characterized the industry for the previous 5 years. Indications of reduced demand and resistance to higher prices were noted in 1975. Mining capacity now appears to be capable of satisfying anticipated demands. Florida output is projected to steadily increase to a level of about 50 million Mg (55 million tons) per year by 1980 and remain near that level for 10 to 20 years.[6]

MINING OPERATIONS WITH POTENTIAL FOR FUGITIVE DUST

Mining operations have no established classification. The Council on Environmental Quality Report to Congress[7] on coal surface mining and reclamation identified nine discrete operations associated with surface mining: construction of access roads, scalping or clearing of vegetation, drilling and blasting to fracture the overburden, removal and placement of overburden, removal of the coal, rehandling and grading of the overburden, revegetation, water drainage control, and sediment basin construction. In an air quality study of mining,[8] Environmental Research and Technology described the operations somewhat differently: topsoil removal and placement, overburden removal and redistribution, coal removal and transport, conveying, sorting, crushing, storage, vehicular traffic on unpaved roads, and coal fires.

The breakdown of operations used in this report is oriented toward isolation of specific dust-producing activities. Each of the 11 operations identified (see Table 4) is described and all available emission estimates are compiled and compared. Variables affecting emission rate also are discussed, e.g., climate and size of material being handled.

All of the 11 operations are not found in every type of mine, and in some cases an operation is only a significant dust

TABLE 4. DUST-PRODUCING OPERATIONS BY MINING INDUSTRY

Operation	Mining industry Coal	Copper	Rock	P_2O_5 rock
Overburden removal	x	+	+	x
Blasting	+	x	x	o
Shovels/truck loading	x	x	x	o
Haul roads	x	x	x	o
Truck dumping	+	x	x	o
Crushing	+	+	x	o
Transfer & conveying	+	+	+	x
Cleaning	o	o	o	o
Storage	+	+	x	x
Waste disposal	+	x	o	+
Reclamation	x	o	+	x

x = Usually a major source.

+ = A minor or occasional source.

o = Usually not a dust source.

source at one type of mine. The operations that usually are dust sources within a particular mining industry are shown in Table 4.

In estimating the total fugitive dust emissions from a mine, it is preferable to identify the dust-producing activities present and estimate the emissions from each one separately rather than to use a single emission factor for the entire mine. The former procedure permits direct determination of the major source areas--the ones needing control--and results in accurate assessments even if the mine has some atypical processes.

Overburden Removal

Description--

Overburden removal, an operation in almost all surface mining, entails removal of all topsoil, subsoil, and other strata overlying the deposit to be mined. Significant advances in methods of surface mining have occurred in recent years with the development of giant excavating and hauling equipment designed specifically for these operations.

In 1965, coal surface mining was not considered feasible unless the overburden depth to seam thickness was 10:1 or less--i.e., a coal seam 1.5 m (5 ft) thick to justify removal of 15 m (50 ft) of overburden. With the introduction of larger equipment, this range of overburden-to-seam thickness has increased to as much as 30:1. Removal of up to 60 m (200 ft) of overburden is now feasible for coal mining, whereas the average in 1965 was 14.6 m (48 ft).[9]

The three major types of coal strip mining are area, contour, and auger. Area strip mining is used where the terrain is relatively flat. Large-scale excavation equipment, usually draglines, remove the overburden material and deposit it in spoil banks in a trench left by the previous strip. Thus, only the initial strip produces waste overburden that must be disposed of or stored for land reclamation. Trenches excavated by draglines are normally about 30 to 60 m (100 to 200 ft) wide.

When the land to be mined has slopes greater than about 15 degrees, contour strip mining is usually employed. In this mining method, the overburden is removed from the slope to create a flat excavation, or bench, resulting in a vertical highwall on one side and a downslope pile of spoils on the other side. The exposed deposit is then mined and the land reclaimed by backfilling the previously worked area with newly removed overburden. If a pattern of backfilling to the original or similar contour is carried out concurrently with the mining and the backfilled land is revegetated, the mined area usually can be successfully reclaimed. Leaving the spoils on the downslope can result in landslides and prevent reclamation.

The third type of strip mining--auger mining--is usually done in conjunction with contour mining. The deposit exposed in the highwall by the contour method is mined by using large drills or augers to pull the deposit horizontally from the seam.

A national bill to regulate surface mining of coal has been passed by the Congress on two different occasions. However, partly because of the steep slope performance standards contained in both bills, the President has vetoed them. Pennsylvania and West Virginia, where contour and auger coal mining methods are more frequently used, have laws prohibiting spoils on downslopes. In West Virginia, all but the last 6 m (20 ft) of the highwall must be recovered and in Pennsylvania all of the highwall must be recovered.

As demand for complete land reclamation grows, more overburden material is being segregated. Topsoil and other subsoil components suitable for revegetation are removed and stored separately. The contoured spoil banks are covered with these two layers during the reclamation process. This greatly increases the ability to revegetate and reclaim the land. It also increases the time and cost of overburden removal; bulldozers and scrapers are required for removing up to 1.5 m (5 ft) each of topsoil and other subsoil strata and transporting this soil to storage areas.

In other types of surface mining such as open-pit mining and quarrying, overburden removal may be only a one-time or occasional operation rather than continuous. For these types of mines, the deposit to be removed is of the same magnitude or larger than the overburden volume and the location of the mining activity is relatively fixed. Therefore, the overburden is removed permanently and may be transported off-site for disposal.

Three kinds of equipment are used to excavate overburden in typical surface mining operations:

- Draglines
- Shovels
- Small mobile tractors, including bulldozers, scrapers, and frontend loaders

Most surface mining operations use these equipment items in varying combinations.

Draglines are electrically powered equipment capable of moving large amounts of material with a bucket capacity ranging from 23 to 168 m^3 (30 to 220 cu yd). [Overburden has an average density of 1.5 Mg/m^3 (1.3 ton/cu yd).] The dragline moves along the surface or bench, positions its bucket on the overburden to be removed, and loads it by dragging it toward the machine. The loaded bucket is then lifted, the machine rotated, and the bucket dumped in an area that has already been mined. Alternately, the excavated material may be temporarily stockpiled and later moved by truck to a final disposal site.

Large diesel or electrically powered stripping shovels have been used in surface mines for a number of years. They are specifically designed for a particular mine operation. These machines proceed along a bench, scooping up fragmented overburden in buckets with capacities of up to 99 m^3 (130 cu yd). In the largest surface mines, shovels are often used in conjunction with draglines.

Typically tractors are used either in small mines or in conjunction with larger, more specialized equipment in large mines. The principal advantages of tractors are their maneuverability, their ability to negotiate steep grades, and their ability to dig and transport their own loads. They are used for a variety of tasks, including clearing, topsoil removal, bench preparation, and leveling of spoil piles.

A fourth type of excavation equipment, the bucket wheel excavator, is seldom used in this country. It has a rotating bucket wheel mounted at the end of a boom up to 120 m (400 ft) long. As the wheel rotates, the buckets along the perimeter are loaded when they cut into the deposit with an upward motion. Continuing rotation causes the buckets to be inverted and empty into a conveyor which then transports the material to a disposal area. Only very large mines with suitably soft overburden material can justify the expense of this equipment.

Emission Estimate

Two primary fugitive dust sources are associated with overburden removal:

- Dumping of dragline buckets or shovels full of overburden material into adjacent trenches or spoil banks, as shown in Figure 5.
- Operation of scrapers and bulldozers in topsoil and subsoil removal and transfer.

If the overburden material must be transferred to trucks for removal, the emissions from loading, travel on haul roads, and dumping are considered with the emissions from these other mining operations.

No sampling has been done specifically to measure emissions from either of these two primary sources. However, some emission estimates have been made. Hittman estimated 0.001 kg/Mg (0.002 lb/ton) of coal mined as the average emission factor nationally for excavation at coal surface mines where area stripping was used, and 0.0015 kg/Mg (0.003 lb/ton) of coal mined by contour stripping.[9] For uncontrolled mining in the Southwest (primarily the Four Corners area), the emission factor estimated by Hittman was 0.13 kg/Mg (0.26 lb/ton) of coal; with controls (assumed to

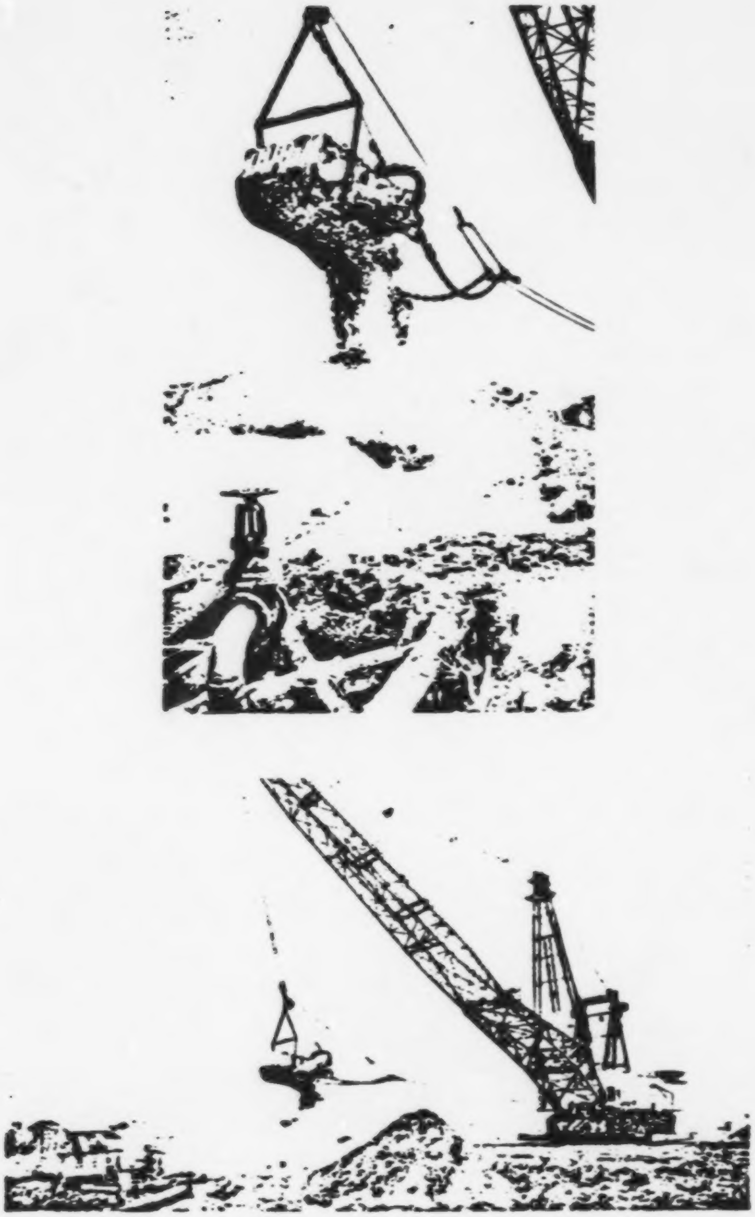


Figure 5. Overburden removal.

Source: Phosphate, Florida Phosphate Council, p 6.

be watering), fugitive dust emissions were estimated to be 0.0045 kg/Mg (0.009 lb/ton of coal). Battelle estimated the total fugitive dust emissions from surface mining of coal in Western states to be 0.005 kg/Mg (0.1 lb/ton) of overburden removed and indicated that overburden removal was the largest emission source at these mines.[10] Considering the common ratios of overburden removed to coal mined (5:1 to 20:1), Battelle's factor appears to be an order of magnitude higher than Hittman's value. The conclusion drawn from both of these references is that emissions from strip mining and particularly the overburden removal process vary considerably geographically, presumably because of the much drier climate in the Western states.

PEDCo estimated that the dragline operation at a lignite surface mine in North Dakota had an uncontrolled emission rate of 0.025 kg/Mg (0.05 lb/ton) of overburden removed, primarily resulting from dumping of the excavated material from a height of at least 30 m (100 ft) into the trench. For the particular mine surveyed, this was equivalent to 0.21 kg/Mg (0.42 lb/ton) of lignite mined. In addition, each of three scrapers stripping the topsoil and subsoil layers were estimated to produce fugitive dust emissions of 7 kg/hr (16 lb/hr) of operation, or a total of 0.015 kg/Mg (0.03 lb/ton) of lignite mined on an annual basis. These estimates were made by comparison with emission rates from similar fugitive dust sources that had been tested, such as construction and aggregate handling. The resulting emission estimates of 0.225 kg/Mg (0.45 lb/ton) of lignite or 0.027 kg/Mg (0.054 lb/ton) of overburden removed compare well with Battelle's average factor if it is assumed that about half of the total strip mining emissions results from the overburden removal operation (the value was 63 percent for the particular mine that PEDCo surveyed).

Engineering Research and Technology (ERT) has provided input[8] to the Bureau of Land Management on the air quality aspects of coal development in northwest Colorado for an Environmental Impact Statement.[11] They proposed an emission factor of

0.0024 percent of the material moved [0.024 kg/Mg (0.048 lb/ton)] for topsoil removal, overburden removal, or coal removal, including a correction for climatic conditions and control measures (watering) at the mines. This emission rate was obtained by applying a published emission factor[12] for aggregate handling and storage to the overburden handling operation, then reducing that emission rate by a factor of three because the material at the mines is coarse broken rock containing few fines rather than aggregate. This emission rate was further reduced to account for lack of fugitive dust on wet or frozen days. The resulting factor agrees quite well with the PEDCo value for mining in a similar climatic area, especially considering the rather crude methods of approximation used in both cases.

Overburden removal in copper mining, rock quarrying, and phosphate rock mining may be much less of a fugitive dust source than in coal mining for several reasons:

- Much less overburden material is handled in open-pit mines and quarries.
- If the overburden material is to be removed permanently, no segregation and separate handling of topsoil fractions are required.
- Phosphate rock deposits in Florida and other Southeastern states are generally mined in areas where the water table is near the surface; therefore the overburden has a high moisture content and does not produce dust when moved. Average overburden depths in Florida are about 6 m (20 ft).
- If the overburden depth is fairly shallow, the excavated material will not be dropped as far from the dragline bucket or shovel to the trench or spoil bank; therefore it creates less of an impact and less opportunity for dispersion of airborne material.

PEDCo estimated uncontrolled particulate emissions from dragline operations at an open-pit copper mine in Butte, Montana, to be 26 Mg/yr (29 ton/yr).[13] No data were obtained on the amount of overburden removed annually; the emission rate per ton of ore mined was 0.0004 kg (0.0008 lb), almost negligible in comparison with the factor for coal mining. The excavation area was noted to be moist and nondusting; emissions were estimated by assuming the active dragline operation of one hectare (2 acres) to be equivalent to an active construction site, using an emission factor of 2.7 Mg/hectare/month (1.2 ton/acre/month).

The Battelle, PEDCo, and ERT data show that overburden removal is potentially one of the largest fugitive dust sources at surface mines. It is also one of the most variable.. The dust losses from this operation vary with the composition, texture, and moisture content of the overburden material, excavation procedures, equipment employed, etc. The emission rate from any specific mine is probably most closely related to the amount of overburden moved.

Blasting

Description--

Drilling and blasting are done to fracture hard, consolidated material so it can be removed more easily and efficiently by the excavating equipment. Blasting may be needed for removal of certain impenetrable overburden or for partings between the seams being mined, but more commonly for loosening the deposit itself. This operation is a routine part of open-pit mining and quarrying; its use in surface coal mining is dependent on the depth and hardness of both the overburden and the coal bed; it is almost never required with phosphate rock mining.

The blastholes are drilled from the surface of the rock layer or deposit to the depth to which the deposit is to be broken. Shelves of 9 to 15 m (30 to 50 ft) depth are often used if a deposit of great thickness is being mined. A flat bench is first prepared for the drilling rig, which is mounted on a tractor or truck. The holes are drilled in a predetermined pattern by an electrically powered rotary drill 10 to 38 cm (4 to 15 inches) in diameter. Larger holes (containing more explosives) are drilled for fracturing rock than for breaking coal. Typical blasting patterns range from 6 m by 6 m (20 ft by 20 ft) to 15 m by 30 m (50 ft by 100 ft), with the blasthole spacings varying with the material to be fractured. When a particularly resistant rock formation is encountered, a pneumatic drill may be required.

Normally, the explosive is a mixture of ammonium nitrate and fuel oil. When a more powerful explosive is required, either dynamite or metalized mixtures such as ammonium nitrate and aluminum can be used. From 140 to 5000 kg (300 to 11,000 lb) of explosive is charged into each hole, depending on its depth, location in the pattern, and the material encountered in drilling. Millisecond delays in the blasting sequence are programmed to maximize the breaking effect and to minimize seismic shock. With small blasts, mats may be used to reduce the scattering of rock fragments.

Blasting is rarely done more than once per day and may be much less often. For safety reasons and to minimize disruption of other mining activities, blasting is usually conducted between work shifts. Also, the area to be blasted must be cleared of equipment and workers while the holes are being charged and wired for detonation, so drilling and blasting are generally as isolated from other active mining operations as possible.

Emission Estimate--

Emissions sampling during drilling and blasting operations at one granite quarry indicated rates of 0.0004 kg/Mg (0.008 lb/ton) of granite quarried from drilling and 0.08 kg/Mg (0.16 lb/ton) from blasting.[14] Of 11 different processes Monsanto Research sampled at this quarry (not the same 11 mining operations described herein), blasting produced the most emissions, accounting for 63 percent of the total fugitive dust emissions from the quarry and crushing plant.[14] More explosive charge is required for blasting granite than any other ore. The results of this study have led Monsanto Research to schedule further field testing of emissions from blasting.

PEDCo estimated emissions from daily blasting at a large open-pit copper mine to be about 90 kg (200 lb) of suspended material per blast, or about 0.0005 kg/Mg (0.001 lb/ton) of ore. This estimate was based on visual observation and is considered only an order-of-magnitude value. The two available emission factors differ greatly, possibly because of the unreliability of the PEDCo estimate or perhaps because of actual differences between the amounts of dust generated by the two blasting operations. The additional scheduled testing may resolve this question.

Blasting is a difficult operation to sample because of its short duration and the danger of placing sampling equipment or men close enough to the area of the expected plume prior to the blast. Also, the force of the blast throws much material into the air that is larger in particle size than suspended particulate. Distinction of this settleable material (which may have a much greater mass) from the suspended fraction may not be possible at the time of the sampling; particle sizing analysis on the collected sample and correction for the percent by weight of settleable particulate may be necessary. Observation of film footage of blasting shows that much of the fine dust that remains air borne is actually generated as the blasted rock returns to the surface after being lifted by the force of the blast, not by the initial explosion.[15] The drilling part of this operation is amenable to conventional open-source sampling methods, but these emissions are probably negligible compared to emissions from blasting.

Figure 6 shows the dust plume from a blasting operation. Blasting is not similar to any other fugitive dust source, so development of an emission factor cannot be accomplished by comparison or extrapolation of data from other operations.

This operation is an obvious dust source wherever it occurs. Although its appearance indicates that it is a major source of mining emissions, its time-averaged contribution may be quite small because the emissions occur for only a few seconds per day or week.

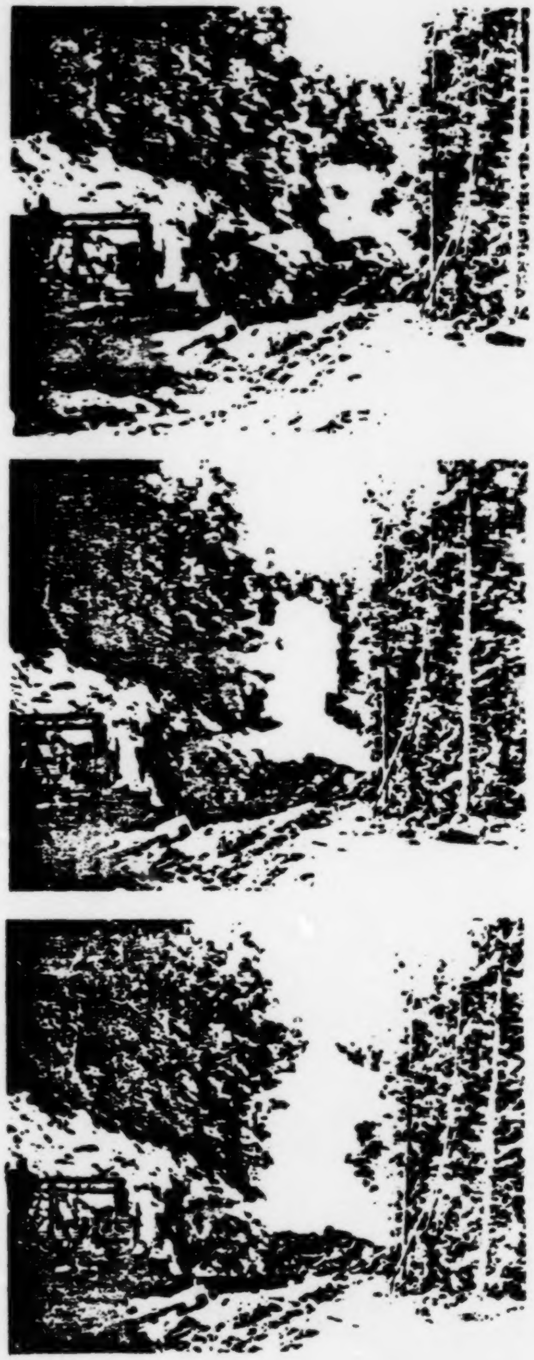


Figure 6. Dust plume from blasting operations.

Shovels Truck Loading

Description--

In most surface mines, the ore or material being mined is loaded onto off-highway trucks for transport from the point where it is removed to a central transfer location or processing area at the mine site. The material can also be transported within the mine in a mechanical or hydraulic conveyor system, but this method is rarely used except in phosphate rock mining, where the deposit is usually pumped as a slurry through a pipeline to the processing area. Another seldom used alternative to shovel and truck operation is the mobile storage bin into which material can be loaded directly by dragline, then crushed and loaded into trucks.

Any of the excavation equipment described earlier can be used to excavate the deposit and load it onto trucks; however, electric-powered, crawler-mounted shovels are most often employed for this purpose because they can load the trucks more quickly. The shovel breaks the fractured deposit loose, scoops the bucket full of material, lifts the bucket and swings it over the truck bed, and releases the load through the hinged bottom of the bucket. When the truck is full, it is driven off and another is moved into position while the shovel is scooping another bucket of material.

The newer haul trucks at mines usually have load capacities of 90 to 180 Mg (100 to 200 tons) and are diesel-electric powered. The trucks may be either end-dumping or the gondola-shaped bottom-dumping, depending on the configuration of the tipple, or dumping area. The same trucks may also carry low-grade ore or unmarketable material in the deposit to a separate dump area for disposal. The loading operation and fugitive dust potential from scooping and loading this waste material are dependent on the material being mined.

A small front-end loader may be assigned to the area being worked by the shovel to remove spilled material that could cause damage to truck tires and to move materials that cannot be easily reached by the less maneuverable shovel. For irregular deposits and smaller mines, a front-end loader may be used instead of an electric-powered shovel.

The area where the shovel is working is normally freshly exposed, so the material has almost the same moisture content as the unexposed deposit. However, traffic movement may cause the truck loading area to dry rapidly. It is difficult for watering trucks or other control equipment to gain access to truck loading areas because of the danger of driving near the mining equipment or haul trucks (which have poor close range visibility) and because the shovel, the deposit, and the power line for the shovel often block access from all but one direction.

Emission Estimate--

Dust is generated at many points in the truck loading operation, but mainly by the scooping of loose material by the shovel, dumping from the shovel bucket into the truck and movement of trucks into position to be loaded. Dust generation from truck loading is shown in Figure 7. Several emission estimates have been made for the entire operation. Midwest Research Institute sampled the loading of crushed rock by front-end loaders and determined an average emission rate of 0.025 kg/Mg (0.05 lb/ton) of rock.[12] This emission factor was also applied by PEDCo to loading of copper ore by shovels as the following differences in the two operations were thought to offset one another:[13]

- the shovel must break the fractured rock loose instead of just scooping it out, resulting in higher emissions than from loading of aggregate;
- the shovel is not as maneuverable as a front-end loader and therefore drops the rock a greater distance into the truck;
- the crushed rock tested was very dry and contained a substantial amount of fines compared with moderate moisture content and few fines in the shovel operation; and
- the crushed rock loading was exposed to higher wind speed conditions than the copper ore loading.

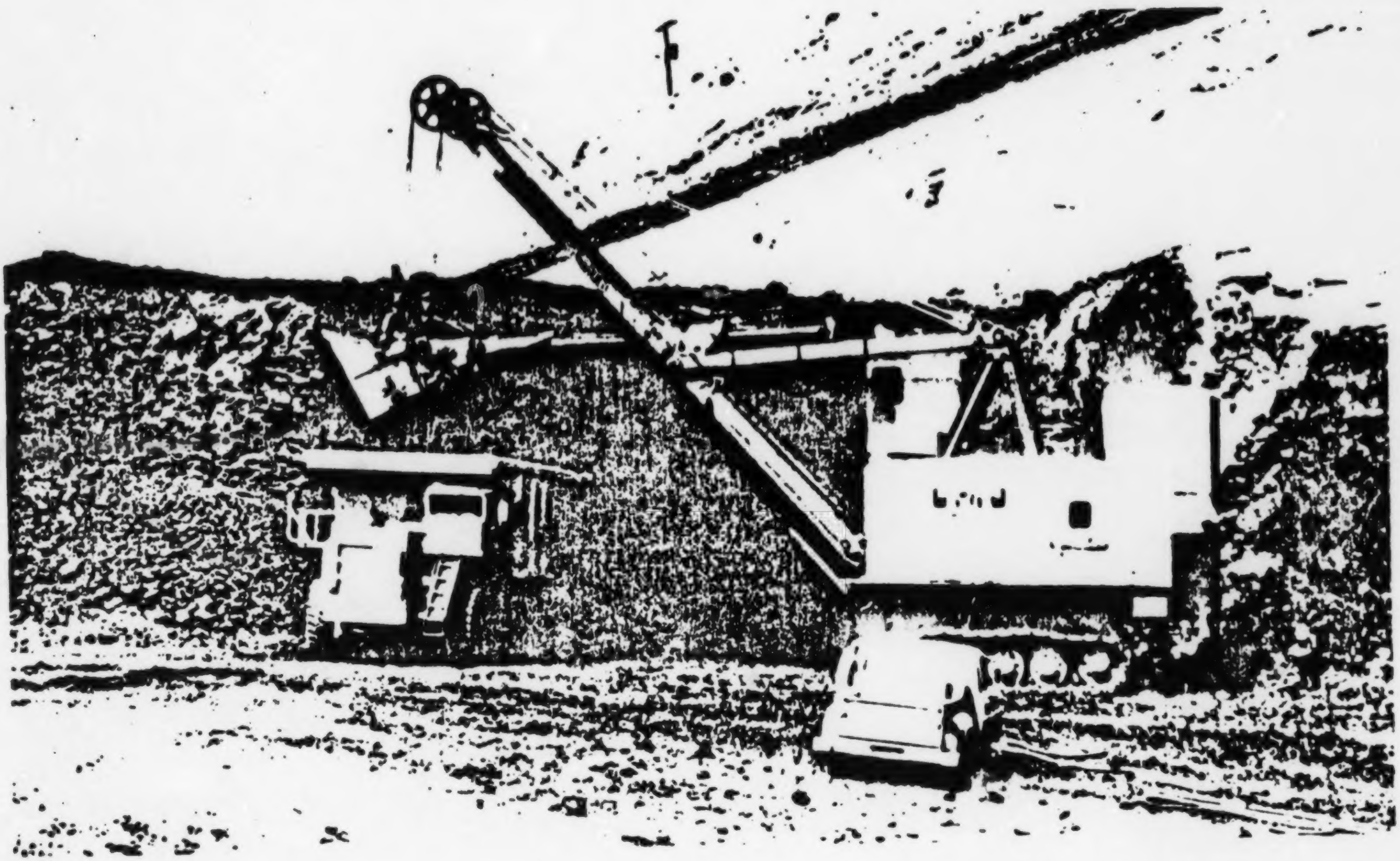


Figure 7. Truck loading.

Source: Draft EIS, Eastern Powder River Coal Basin, 1974, p I-74.

The effect of the shovel's larger bucket size on emission rate could not be determined.

The PEDCo emission factor estimate for loading lignite coal in North Dakota is 0.01 kg/Mg (0.02 lb/ton) loaded. This lower estimated emission rate is based on comparison with loading of crushed rock, considering the higher moisture content and fewer fines in the lignite. The lower value also appears reasonable in comparison with emissions from other operations at the lignite mine, such as truck dumping and grader operation.

The ERT air quality analysis of Colorado coal mines cited earlier proposed the same emisssion factor for coal removal and loading as for overburden removal, 0.024 kg/Mg (0.048 lb/ton). This value is almost the same as those developed for crushed rock and copper ore, and may be a function of lower moisture content in the coal from beds in northwest Colorado than in North Dakota lignite.

Monsanto Research's sampling at a crushed granite plant indicated that loading onto haul trucks produced negligible emissions,[14] reportedly because of the large aggregate size, i.e., the absence of fine granite dust.

The Hittman report included an emission factor of 0.04 percent due to "windage losses" in truck hauling at coal mines.[9] It was indicated that most of these emissions occurred at the two ends of the hauling trip--loading and dumping--and that most of the weight loss was probably as airborne particulate. However, much of the airborne particulate could still be due to settleable material. If it is assumed that half of the total "windage losses" of 0.4 kg/Mg (0.8 lb/ton) (0.04 percent) occurs during loading and that 25 percent of this material remains suspended, the emission estimate for truck loading would be 0.05 kg/Mg (0.10 lb/ton). This is higher than the other estimates, but certainly close enough to confirm the relative magnitude of these other values.

Independent estimates of emissions from the truck loading operation cover a fairly wide range, possibly indicative of the many variables involved in this operation. The most important of these variables are the moisture content and amount of fines in the material being loaded, the number and types of equipment working in the loading area, and climatic conditions at the mine.

Haul Roads

Description--

Haul roads, mostly temporary unpaved roads between the active mining areas, tipple, waste disposal areas, and equipment service areas, are common to all surface mines. In a typical mine, these roads constitute about 10 percent of the total area directly disturbed by the mining.[16] Because of the size of the trucks and crawler-mounted equipment that use these roads, they are normally constructed at least 12 m (40 ft) wide. In mines opened in recent years, particularly those in the West that use 90 to 180 Mg (100 to 200 ton) capacity trucks, the roads may be as wide as 30 m (100 ft).

Some of the haul roads at the mine lead from bench level at the bottom of the deposit to undisturbed surface elevations, which may be 60 to 90 m (200 to 300 ft) higher. Therefore, these haul roads either have a steep grade or follow a circuitous route to the higher elevation. In areas where contour mining is practiced and lighter equipment is used, the roads generally exhibit poor alignment and drainage, low durability, and marginal maintenance. Where area mining is practiced with its attendant heavy equipment, roads are necessarily better engineered.

Road surfaces vary according to the terrain, type of operation and size of equipment used. The surfaces may be graveled but more commonly they are just graded. In areas of flat open terrain, the roads are graded with berms thrown up at the road edges from excess material generated during grading or maintenance. In Eastern states, where mine operations are located in hilly or forested terrain, the use of berms is often prohibited or discouraged because of its adverse drainage effect.

While in use, haul roads are normally cleared of spilled material and regraded frequently. Heavy equipment tends to rut and compact the surface. Continuous maintenance of haul roads used by heavy equipment makes higher speeds possible and provides greater usage time of the roads. Generally, the haul roads are built and maintained as cheaply as possible without slowing down production from the mine. At any given time, only a portion of the roads at the mine site will be active, but the abandoned roads are left as is for possible reuse when that mining area becomes active again. In the interim period, they serve a definite purpose by providing good access throughout the mine.

In addition to the haul trucks, other vehicles use the haul roads regularly--water trucks, fuel and service trucks, pickup trucks, motor graders, bulldozers, and explosives trucks. The vehicle miles traveled (VMT) per day on haul roads can be estimated from the numbers of each type of vehicle in operation at a mine and their respective driving patterns (e.g., round trip distance from loading area to tipple and number of loads per shift per truck). Alternatively, the VMT can be estimated from total gasoline and diesel fuel usage and average fuel consumption rates for the different vehicles.

Haul roads at mines are routinely watered for dust suppression during all periods when water on the road surface does not create a safety hazard (generally when temperatures are above freezing). The water is usually applied by large tank trucks equipped with a pump and directional nozzles which spray the road surface and adjacent shoulders and berms. Fixed pipeline spray systems have also been used on main haul roads that are relatively permanent. Various chemicals may be added to the water or applied separately to the road surface to improve binding and reduce dusting. Over 100 dust suppressant materials are now marketed, and many of them have been proven effective for short periods in tests on mining haul roads.[17] As a result of the frequent watering, heavy bearing loads on the road surfaces, and chemical applications, mining haul roads usually have the appearance of oiled or crudely paved roads rather than rural gravel roads.

Emission Estimate--

Several studies of emission rates from unpaved roads have been made during the past few years. However, as already indicated emissions from mining haul roads may differ greatly from those from normal unpaved roads because of the larger vehicles, compacted surfaces, and frequent watering. Figure 8 shows a large-capacity truck on a well-controlled haul road. Close observation of well-controlled haul roads reveals that much of the dust is generated near the edges of the roads, where the surface is composed of looser material, and in areas where the surface has dried. Also, haul roads emit fugitive dust as a result of movement other than traffic--road construction and repair, loss of fines from the open-bed trucks during transit, and wind erosion on abandoned and seldom used roads. Vehicle exhaust contains particulate emissions, but these emissions are not considered and are therefore not included in the emission estimates.

At least three different emission estimates have been made specifically for traffic on unpaved haul roads. The first of these, by PEDCo Environmental, was developed from EPA's published emission factor for unpaved roads:[18]

$$EF = (0.60)\ (0.81)\ (s)\ (S/30)\ (1-W/365) \qquad \text{(eq.1)}$$

where EF = uncontrolled emission factor, lb/VMT

0.6 = average fraction of emitted particulate in the suspended particulate size range (less than 30 μ diameter)

s = silt content, percent

S = average vehicle speed, mph

W = days with 0.01 inch or more of precipitation or reported snow cover

This emission factor was modified to take into account the much larger surface area of the road in contact with the truck tires. It was assumed that the relative emission rates for off-highway

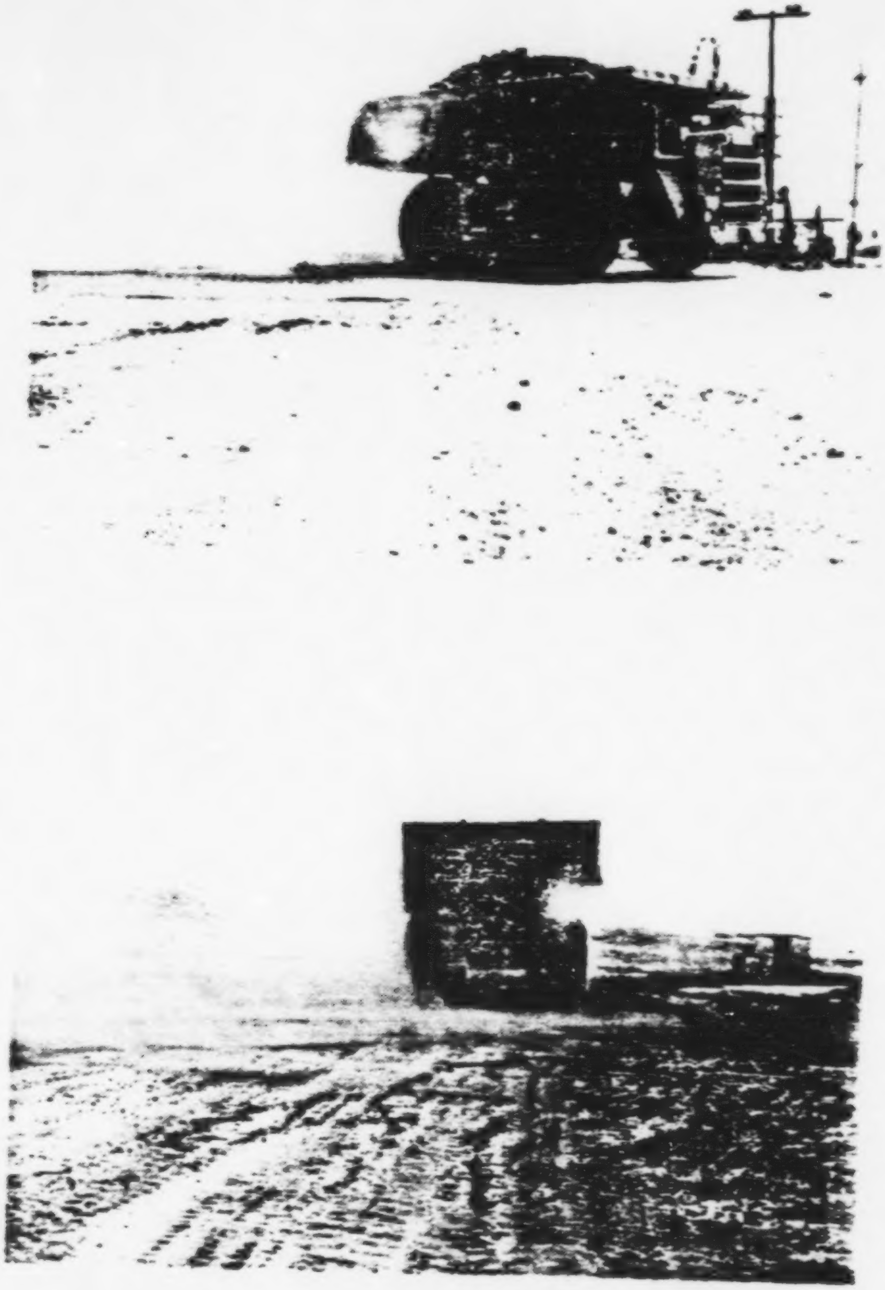


Figure 8. Large capacity truck on a well-controlled haul road.

trucks, even though they have only four tires, would be two and one-half times as great as for light duty vehicles, based on the comparative widths of tire faces. Other input data used to calculate the emission factors for two different mining operations are summarized below:

Parameter	Open-pit copper mine	Lignite surface mine
Average vehicle speed, kph (mph)	24 (15)	32 (20)
Days/yr with no rain or snow cover	274	166
Emission reduction affected by watering and chemicals, percent	80	50
Emission factors, kg/annual VkT (lb/annual VMT)		
Haul trucks	(0.31) 1.1	(0.63) 2.2
Pickup trucks	(0.11) 0.4	(0.26) 0.9

In addition, an uncontrolled emission factor of 15 kg/hr (32 lb/hr) was proposed to apply to grader operations in these PEDCo studies, and the control efficiencies of the graders working on the haul roads and the truck traffic were assumed to be the same. Windage losses in transit were thought to be negligible in comparison with emissions from the road surfaces in these two instances, but when hauling some materials the emissions from the moving trucks could be significant. Wind erosion emissions from the haul roads were assumed to be indistinguishable from wind erosion of other exposed areas at the mines and were therefore considered in another source category.

Monsanto Research's study of a granite quarry showed emission rates from "vehicular movement on unpaved roads" of 0.024 kg/Mg (0.048 lb/ton) of material processed, or about 1.1 kg (2.4 lb) during each round trip to the crusher, assuming 45-Mg (50-ton) capacity trucks and only haul truck traffic on the roads. A conscientious haul-road watering program was reportedly being implemented at the mine during the test program. Since the dimensions of the quarry and hauling frequency were not described, it is not possible to compare this value directly with the other available emission factors. However, it appears to be somewhat lower.

ERT applied a base emission factor of 1.1 kg/VKT (3.7 lb/VMT) (obtained from an early study of fugitive dust emission sources)[17] to both haul trucks and light-duty vehicles at surface mines in northwestern Colorado. This factor was then reduced by multiplying a climatic correction of 0.44, the fraction of days when the surface was not wet or frozen, and a control factor of 0.50 to account for watering of the roads on dry days. The resulting net emission factor was 0.23 kg/VKT (0.8 lb/VMT) for total annual travel at the mine. This value is near the weighted average of emission rates from copper mines, and ERT employed the same rationale as PEDCo in applying correction factors to account for differences between emission rates from normal unpaved roads and mining haul roads.

The available emission factors covering this mining operation are in fairly close agreement. Application of any of these values shows that haul roads are a major fugitive dust source at all surface mines, even with the relatively high control efficiencies obtained with frequent watering and use of chemical dust suppressants. The calculation procedures used to derive the factors indicate that variables that most affect emissions from this operation are vehicle speed, estimated control efficiencies, and climatic conditions at the mine.

Truck Dumping

Description--

Truck dumping is the simplest mine operation to describe--it involves only the dumping of the mined material from the truck into a tipple or the receiving hopper of the primary crusher. The same operation may also occur at the edge of a spoils slope if the truck is dumping waste material or overburden. Although the operation is quite simple, it has been identified as a significant fugitive dust source at many different mines,[13,19] as shown in Figure 9.

Emission Estimate--

Dust is generated as the material tumbles from the truck bed and strikes the ground or side of the hopper. Three different estimates of the emission rate from this operation were located. Midwest Research Institute, in a sampling study of aggregate handling operations, estimated that dumping of crushed rock or gravel onto storage piles accounted for about 12 percent of the total handling emissions of 0.16 kg/Mg (0.33 lb/ton), or 0.02 kg/Mg (0.04 lb/ton.) The truck dumping operation was not sampled in isolation from the other handling operations and the estimate of 12 percent was partially subjective. This emission factor for dumping of aggregate onto storage piles was recently published in Supplement 5 of EPA's Compilation of Air Pollutant Emission Factors.[18]

Monsanto Research determined the emission rate to be 0.00017 kg/Mg (0.00034 lb/ton) from truck unloading at the hopper of a primary crusher.[14] The material being handled was quarried granite in which very little fine material was present.

In two separate studies, PEDCo used a truck-dumping emission factor of 0.01 kg/Mg (0.02 lb/ton). This value was derived by taking half the published EPA emission factor for dumping of aggregate because of the much larger size of the broken ore and coal being handled and its higher moisture content. The 50 percent reduction was based on the estimated control efficiency of watering,[17] which is probably comparable to the effects of higher moisture content and larger material size.

Intuitively, it seems that emissions from truck dumping should be less than from truck loading because dumping does not include the activity of the shovel or front-end loader in loosening and scooping the deposit. In comparison with the truck-

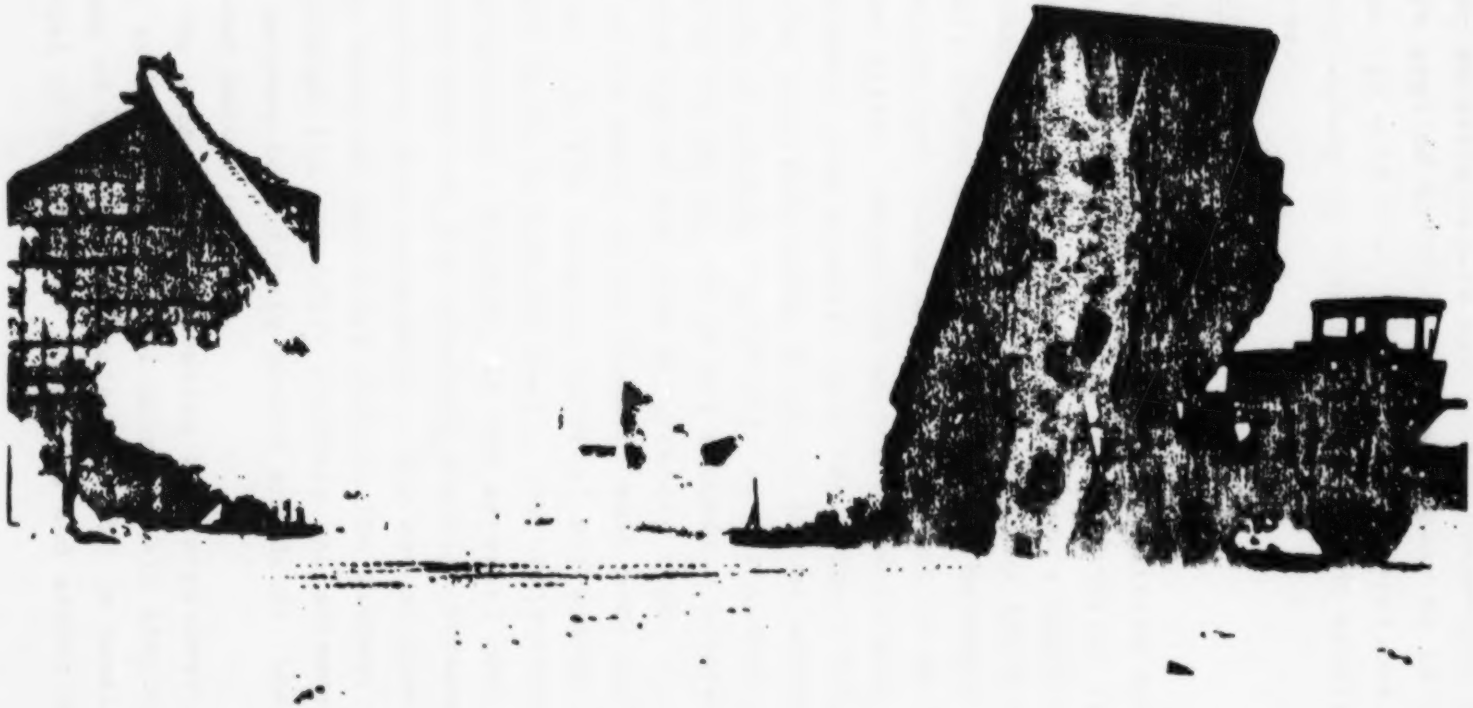


Figure 9. Truck dumping.

Source: Draft EIS, Eastern Powder River Coal Basin, 1974, p I-75.

loading emission values previously presented, the MRI and PEDCo factors applied to truck dumping appear to be quite reasonable. However, as with most of the mining operations, emission rates may vary widely as function of different minerals or different climates.

Crushing

Description--

The crushing operation can be fugitive dust source at both underground and surface mines. The material is charged to the primary crusher by means of a receiving hopper. At large mines, more than one hopper or dumping bin may serve separate primary crushers placed in parallel. Primary crushers are jaw crushers, set to act upon rocks larger than about 15 cm (6 in) and to pass smaller sizes. Depending on the ultimate size requirements of the product, the material from the primary crusher may be screened with the undersize going directly to the screening plant and the oversize to secondary crushing, or all material from primary crushing may be routed to the secondary crusher. The secondary crushers are of the cone or gyratory type.

As the material is crushed, much more surface area is created. If the incoming material has a high internal moisture content (such as lignite coal), the new surfaces will be moist and nondusting. However, if the material has a low internal moisture content, the crushing greatly increases the potential for airborne dust generation. The new surfaces tend to dry out as the material continues through the process on conveyor belts and through the secondary crushers and screens. As the rock or coal becomes more finely ground and drier, the in-process dust released become greater.

One method of suppressing the in-process dust is by adding water to keep the material moist at all stages of processing. If the use of water can be tolerated, it is usually sprayed on the material at the crusher locations and shaker screens. The addition of water may cause blinding of the finest size screens, thereby reducing their capacity.

The crushing/screening operation is either fully enclosed or the dust emission points are hooded, with a local exhaust system, control device, and stack. This is the only operation at the mines that would not be strictly defined as a fugitive dust source, because the emissions are confined and emitted at a single point (as shown in Figure 10). However, most crushing operations still have some fugitive dust losses that escape the hooding system at points such as the crusher discharges and conveyor transfer points. At rock quarries, most of the crushers are portable, are not well enclosed, and therefore usually have particularly high fugitive dust emissions. One estimate of emissions from coal preparation assumed that half the dust generated went through a collection system to controls and half escaped.[8]

Emission Estimate--

EPA's published compilation of emission factors for coal crushing does not include a quantitative estimate, but states that "the crushing, screening, or sizing of coal are minor sources of dust."[20] The writeup on coal crushing also indicates that 95 percent control can be achieved by use of water sprays and 99+ percent control is possible with sprays followed by mechanical dust collectors. The Hittman report[9] also states that dust emissions from coal preparation plants are negligible.

Based on some data from coal processing for coke production, PEDCo estimated[21] that the uncontrolled emission rates from the three major emission points in the operation would be:

Primary crushing = 0.01 kg/Mg (0.02 lb/ton)
Secondary crushing = 0.03 kg/Mg (0.06 lb/ton)
Secondary screening = 0.05 kg/Mg (0.10 lb/ton)

In combination with the estimated control efficiencies cited above, these values appear to substantiate the nonquantitative

Figure 10. Crushing.

evaluations that coal crushing is only a minor dust-producing source.

In contrast, the current EPA emission factors for rock crushing are quite high, as shown below:[20]

Primary crushing = 0.025 kg/Mg (0.5 lb/ton) total
= 0.05 kg/Mg (0.1 lb/ton) suspended particulate

Secondary crushing and screening = 0.75 kg/Mg (1.5 lb/ton) total
= 0.3 kg/Mg (0.6 lb/ton) suspended particulate

It has been noted that even the lower of the two sets of emission factors often overestimates annual emissions from rock quarries in regional emission inventories, indicating that these factors are most applicable to uncontrolled portable cruhsers or must be combined with very high control efficiencies to produce reasonable values. It cannot be determined from the source descriptions where the EPA emission factors include just stack emissions or both stack emissions and fugitive dust losses.

Crushing operations at a granite quarry have been sampled by Monsanto Research.[14] Their results, which include both stack emissions and fugitive dust, are more consistent with expected emission rates than the EPA values:

Primary crushing = negligible

Secondary crushing = 0.009 kg/Mg (0.018 lb/ton)

Secondary screening = 0.013 kg/Mg (0.026 lb/ton)

Transfer and Conveying

Description--

Although conveyor systems may be used to transport material from the active mining area to the processing area or to deliver the processed material to the consumer, conveying most often occurs within the processing area--moving the crushed material to storage, a cleaning process, or the train loading station.

This operation also includes the loading of train cars and other transfer of the material, except for conveyors within the crushing or storage operations, which are considered to be integral to these operations. Because of the large tonnages that must be moved in mining, most of the transport systems are belt conveyors rather than screw, vibrating, or continuous-flow conveyors.

Generally, conveyor runs between processes are less than 300 m (1000 ft). The average length of the few haulage conveyors between pits and crushers is about 640 m (2100 ft),[22] and off-site delivery conveyors of up to 19 km (12 mi) have been built to transport coal.

Loss of material from the conveyors is primarily at the feeding, transfer, and discharge points and occurs because of spillage or windage. A conveyor belt is shown in Figure 11. The total weight loss in transit is certainly greater than the fugitive dust emissions from this operation because much of the spillage is deposited along the conveyor and some of the wind-blown material is in the settleable size range.

Excessive moisture in the material or air currents can create discharge problems on belt conveyors. Therefore, most are enclosed, and in some cases the transfer points may be hooded and vented to a dust collector. Both the enclosure and the hooding greatly reduce fugitive dust emissions from this operation.

Emission Estimate--

Conveying is one of the most variable mining operations with respect to fugitive dust emission rates. Many mines have no belt conveyors or similar transfer processes; the material is moved by truck to the tipple and loaded directly onto trains. Other mines have extensive networks of unenclosed conveyors. Also, the emissions vary greatly according to the different materials conveyed depending in part on size distribution and moisture content.

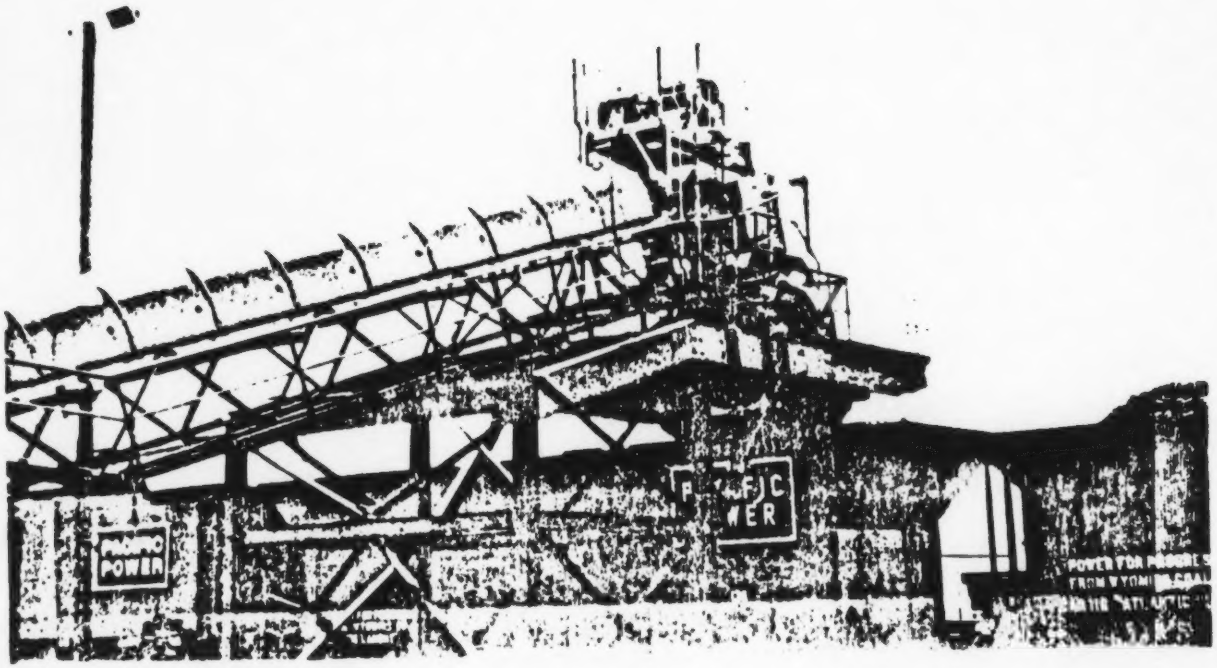

PACIFIC
POWER

Figure 11. Transfer and conveying.

ERT proposed a single emission factor to apply to the combined processing sources at coal mines in northwestern Colorado--0.022 kg/Mg (0.44 lb/ton) 0.044 percent of material processed with half of these emissions fugitive dust. The processing sources at these mines were identified as transfer and conveying, crushing, and storage. Because other emission estimates are available specifically for the crushing and storage operation at coal mines, a value for conveying can be determined by subtraction from the overall ERT emission factor. Using the higher of alternative emission estimates for crushing and storage of 0.09 kg/Mg (0.18 lb/ton) and 0.027 kg/Mg (0.054 lb/ton), respectively, the indicated emission rate for conveying would be 0.10 kg/Mg (0.20 lb/ton). This seems to be excessive when compared with estimated emissions from conveying other material, and may be an indication that other unidentified particulate sources are also included in the ERT emission factor for the processing area. The value of 0.10 kg/Mg (0.20 lb/ton) does not account for the relatively high control efficiencies, usually at least 90 percent, associated with enclosed transfer and conveying systems.

The Hittman report stated that coal conveyor systems "are either covered or operated at such a speed that dusting does not occur to any great extent." Also, it was pointed out that only a small proportion of coal transport is done by this method. However, the same report used a value of 0.04 percent, or 0.4 kg/Mg (0.8 lb/ton), loss through spillage at conveyor transfer points. Even if only a small percentage of the spillage losses is in the form of dust, emissions from coal conveying would be comparable to those from coal storage piles.

Monsanto Research sampled conveying operations at a granite quarry and determined that fugitive dust emissions from conveying crushed granite are also negligible.[14] The report did not mention whether the conveyor was enclosed.

Monsanto Research also sampled phosphate rock storage and handling operations and derived a combined operations emission factor of 0.17 kg/Mg (0.35 lb/ton.[23] With a stated storage emission factor of 0.10 kg/Mg (0.20 lb/ton), the indicated emission rate from handling (conveying and loading onto railroad cars after drying) is 0.07 kg/Mg (0.15 lb/ton). It is assumed that all the handling following drying is in enclosed, controlled systems.

PEDCo developed an emission factor for transfer and loading of dry phosphate rock which agrees well with Monsanto Research's factor. The PEDCo emission estimate of 0.75 kg/Mg (1.5 lb/ton) uncontrolled, with average control efficiencies of 90 to 95 percent, was developed from source test data and company estimates provided by six phosphate industry plants in Florida.

Cleaning

Description--

Cleaning or beneficiation of the ore improves the quality of the mined material by separating undesired components at the mine site. This operation greatly reduces the amount of material that must be shipped to the processing plant and also decreases solids handling and disposal problems in all subsequent refining steps (or the combustion process in the case of coal).

By far the most common method of beneficiation is froth flotation--a slurry of the crushed ore is subjected to aeration in the presence of reagents that selectively separate the mineral being mined from other material in the deposit. To enable the flotation process to work properly, the ore must be crushed or ground small enough to liberate the mineral being extracted. Metallic ores are generally ground finer than 48 mesh and coal and most non-metallic ores should be 20 mesh or finer.

In flotation machines, the ore is suspended in water at a loading of 15 to 35 percent solids by means of air or mechanical agitation. Surfaces of the mineral particles are treated with chemicals, called promoters or collectors, that make the particles aerotropic and hydrophobic. With continued aeration or agitation and the addition of a frother, a layer of foam forms at the water surface. The treated mineral particles become attached to air bubbles, rise to the surface, and are skimmed off. Untreated components collect in the bottom area and are drained off as underflow. The valuable concentrate from froth flotation may be either the froth product or the underflow product. Metallic sulfides of copper, lead, zinc, nickel, mercury, and molybdenum collect in the froth.

The initial low-grade concentrate may be processed through a second "cleaner" flotation cell to remove additional extraneous material. The tailings from the cleaner cells are recirculated through the system or concentrated separately in additional cells. Regrinding of these middlings is necessary in many ores. The tailings or waste material from the flotation machine are discarded in slurry form for easier transport. The final concentrate is dewatered in thickeners and filters prior to shipment.

Well over 90 percent of nonferrous metallic ores are concentrated by froth flotation prior to smelting,[24] and most of the phosphate rock fines in Florida are recovered by flotation. About 70 percent of the coal from underground mines and 30 percent from surface mines are subjected to some type of mechanical cleaning--by jigs, concentrating tables, dense media, or flotation. Of the coal that is cleaned, about 20 percent is thermal dried.[9]

Emission Estimate--

Much of the cleaning operation is performed in water, and even after the concentrate or cleaned material is dewatered it is still wet and nondusting. Only if an unusual cleaning process such as magnetic separation, dry tabling, mechanical classification, or air blowing is used does this operation have any potential for fugitive dust generation.

Thermal dryers at coal cleaning plants are significant particulate air pollution sources, but they are not categorized as fugitive dust sources. Emission estimates for the common types of coal dryers are presented in EPA's Compilation of Air Pollutant Emission Factors, along with estimated efficiencies of various control devices:

Type dryer	Uncontrolled emissions, kg/Mg	(lb/ton)
Fluidized bed	10	(20)
Flash	8	(16)
Multilouvered	12	(25)

Cleaning has been included as a mining operation with potential for fugitive dust emissions mainly for completeness. At most mines, no emissions are associated with this operation. No emission factors were found in the literature for sources other than the theraml coal dryers.

Storage

Description--

This operation involves any open storage pile of mined material that is located at the mine site, either prior to or after some initial processing. The storage piles may be short-term with a high turnover to accomodate irregular daily or weekly throughput rates of different sequential processes, or may provide a long-term reserve for emergency supplies or to meet cyclical seasonal demands. Frequently, however, no stockpiling of material occurs at the mine site because of the extra handling required.

The material is usually placed on the storage pile by means of tipple arrangement or a conveyor, as shown in Figure 12. Equipment such as bulldozers, front-end loaders, and small shovels may be used to move material within the storage area or position it for loading out of storage.

The emission estimates presented in this section with the exception of dry phosphate rock, apply to unenclosed storage piles. In cold or wet climates the material may be placed in storage silos, from which it can be loaded directly into unit

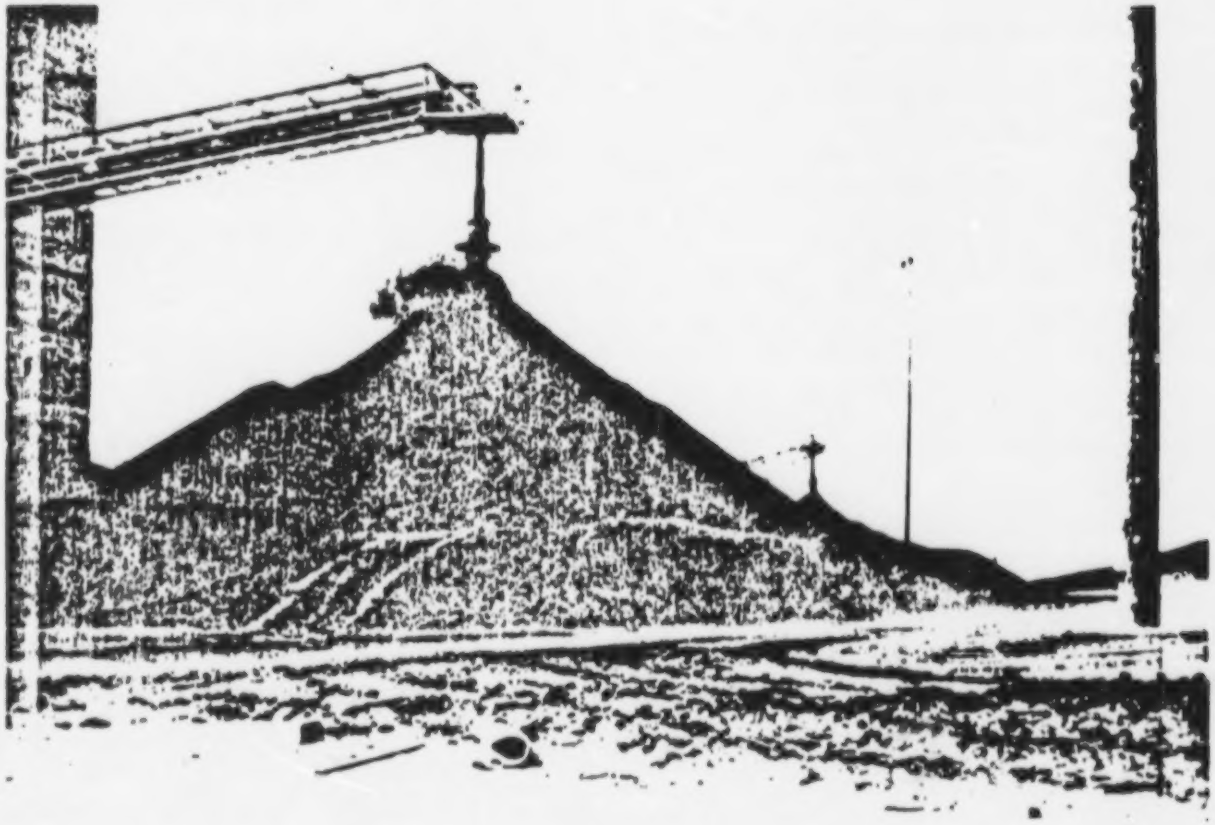


Figure 12. Storage.

trains. Silos vary in diameter, height, and number depending on mine production and train scheduling. Typical silos are about 45 m (150 ft) high and 21 m (70 ft) in diameter, with a capacity of approximately 10,000 Mg (11,000 tons). The only fugitive dust losses associated with silos or other enclosed storage facilities are from transfer and conveying, which are considered as a separate operation (see Subsection 2.2.7).

Also, the storage operation as defined herein does not include topsoil or waste material storage. These are also parts of other operations, reclamation and waste disposal.

Emission Estimate--

Fugitive dust emissions from the storage area occur as a result of several activities. According to sampling data compiled and evaluated by Midwest Research Institute,[12] the following are the four major emission-producing activities in crushed rock storage. Also listed are their approximate relative contributions:

Loading onto piles	12%
Equipment and vehicle movement in storage area	40%
Wind erosion	33%
Loadout from piles	15%

Although the percentage contributions from these activities may vary according to the material stored or the specific storage area configurations, the same activities are probably the major dust sources in all types of open storage.

The MRI study produced emission factors applicable to a wide range of aggregate storage operations, possibly including crushed ore storage. These values are summarized in Table 5. MRI also developed a climatic factor to correct the emission estimates shown in Table 5 for different geographic areas: $(100/PE)^2$, where PE is the annual precipitation-evaporation index.* EPA has adopted the MRI emission factor based on tonnage throughput for

Table 5. EMISSION FACTORS FOR CRUSHED ROCK STORAGE PILES

Activity rating	Emission factor	
	kg/hectare(lb/acre) of storage/day	kg/mg(lb/ton) placed in storage
Active[a]	14.8 (13.2)	0.21 (0.42)
Inactive (wind erosion only)	3.9 (3.5)	0.055 (0.11)
Normal mix[b]	11.6 (10.4)	0.165 (0.33)

[a] Eight to 12 hours of activity per 24-hr period.

[b] Five active days per week.

Source: Development of Emission Factors for Fugitive Dust Sources, U.S. Environmental Protection Agency, Research Triangle Park, North Carolina, Publication Number EPA 450/3-74-037, June 1974.

storage piles with a normal mix of activity for publication in the latest supplement to their Compilation of Air Pollutant Emission Factors: $0.16/(PE/100)^2$ kg/Mg [$0.33/(PE/100^2$ lb/ton].

The Hittman report contained estimates of emissions from aboveground coal storage in only two coal mining areas, the West (Powder River Basin) and the Southwest (Four Corners area). In the West, emissions were assumed to be "minimal" because of the rapid turnover of coal in storage. The emission factor for coal storage in the Southwest was 0.01175 kg/Mg (0.0235 lb/ton) based on the average wind erosion rate in arid portions of the Great Plains, 480 kg/ hectare/yr (428 lb/acre/yr). The coal at the single mine for which this estimate is applicable is stored in piles 30 m (90 ft) wide, 240 m (800 ft) long, and 10 m (30 ft) high, containing about 27,000 Mg (30,000 tons) of blended coal.

Monsanto Research sampled a coal storage pile to determine losses. On two separate runs, the coal pile produced emissions at rates of 0.0045 kg/Mg (0.009 lb/ton) and 0.008 kg/Mg (0.016 lb/ton) in the pile (static rate); these were converted to an annual emission rate of 0.027 kg/Mg (0.054 lb/ton) placed in storage by use of additional information on the storage throughput rate.[23] It was indicated that no loading or unloading took place in the storage area during either of the sampling periods.

Monsanto Research sampled a phosphate rock storage pile during a similar study and developed an average emission factor of 0.10 kg/Mg (0.20 lb/ton) of "wet" rock in open storage. The phosphate rock may be shipped wet to the chemical processing plant or it may be dried at the mine site. Because it is difficult to handle the material after it has been dried, the trend is toward locating the dryers and grinders at the chemical processing plant rather than at the mine. However, if the phosphate rock is dried on-site, then subsequent storage prior to shipment

---

* A national map showing PE values for all parts of the country can be found on p. 99 of EPA's Compilation of Air Pollutant Emission Factors, Supplement No. 5.

is a major fugitive dust source even though the dry phosphate rock must be stored in an enclosure. EPA's published emission factor for transfer and storage of dry rock is 1.0 kg/Mg (2.0 lb/ton) uncontrolled.[20] Source test data and company estimates of material loss collected by PEDCo for nine phosphate industry plants and mines in Florida indicated exactly the same average uncontrolled emission rate as the EPA value --1.0 kg/Mg (2.0 lb/ton). However, the use of baghouses or scrubbers on vents and at transfer points within storage buildings can achieve control efficiencies of 90 to 95 percent.

Waste Disposal

Description--

Large amounts of waste material are often generated in the mining and beneficiation of minerals and ores. Examples of this waste material are low-grade ore, slack coal, extraneous unmarketable rock of relatively large size, tailings, coal slurry, and mud slime. The waste may have the same handling characteristics as the raw material being mined and be disposed of in a fill such as shown in Figure 13 (e.g., a waste dump, leach pad, or gob pile), or the waste may be a slurry, resulting from a cleaning or separation process, that requires ponding.

The waste disposal operation is distinguished from overburden disposal because in most cases the area used to dispose of wastes is not reclaimed. The wastes sometimes are segregated and saved for future reprocessing or by-product recovery; at times they are segregated because they contain higher concentrations of toxic materials than the overburden. If the waste contains no potentially recoverable material and its toxic components do not create a leaching problem, it can be disposed of by burying in the spoils.

Some of the activities associated with waste disposal are the same as for the mining of the ore, i.e., truck loading and dumping, haul road traffic, scraper operation, and grader operation. For purposes of estimating emissions by unit operation at

Figure 13. Waste disposal.

Source: Environmental Protection in Surface Mining of Coal, U.S. Environmental Protection Agency, EPA 670/2-74-093, 1974, p 66.

the mine, movement of waste material should not be considered a distinct operation from the primary activity (e.g., shovel/truck loading) unless it employs different equipment or occurs at a separate location, such as the dump site.

The other aspect of waste disposal is the disposal site itself. If berms or dikes are constructed to contain a slurry waste, this activity is part of the waste disposal operation. Also, dried or inactive ponds of fine waste material, particularly copper tailings, are subject to severe wind erosion if they are not stabilized.

Waste disposal at coal mines creates another potential particulate air pollution source--spontaneous combustion of coal refuse piles and gob piles. However, burning coal waste piles are not fugitive dust sources, so they are not included within the scope of this report.

Emission Estimate--

Excluding the disposal site, most of the fugitive dust-producing processes associated with waste disposal involve the same equipment and activities as other mining operations. Therefore, their emissions can be estimated by comparison with these operations and application of appropriate emission factors.

The equipment activity at the disposal site, such as berm construction or grading of a leach pad, can generally be categorized as heavy earthwork construction. It may be appropriate to apply the heavy construction emission factor from Supplement 5 of EPA's Compilation of Air Pollutant Emission Factors--2.7 Mg/hectare (1.2 ton per acre) of active construction per month. However, this value is applicable only in arid Western areas where the sampling was done to develop the emission factor.[12]

PEDCo developed estimates of emissions from dried tailings by using the U.S. Department of Agriculture's wind erosion equation.[25] These estimates are a function of regional climatic conditions and assume no surface crusting:[17]

Climatic factor	Emissions, Mg/Hectare per yr (ton/acre per yr)
0.1	2.9 (1.3)
0.2	5.8 (2.6)
0.3	9.0 (4.0)
0.4	11.9 (5.3)
0.5	14.8 (6.6)
0.6	17.9 (8.0)
0.7	20.8 (9.3)
0.8	23.7 (10.6)
0.9	26.9 (12.0)
1.0	29.8 (13.3)
1.2	35.8 (16.0)

If complete crusting of the fine tailings material occurs, emissions are reduced by about 80 percent. Approximately the same emission reductions can be achieved by either chemical or vegetative stabilization of the tailings.

Emissions occur from most waste dumps and gob piles when the material is dumped onto the pile but probably no additional emissions result from wind erosion because no small particles are on the surface.

No other references were found that identified waste disposal operations as significant fugitive dust sources. With the exception of tailings pile erosion at certain types of mines, waste disposal is generally a very minor dust-producing operation.

Land Reclamation

Description--

All surface mining causes considerable alteration of the land on which it occurs and a certain amount of the surrounding area as well. Experience has shown that the most successful land reclamation results when programs are preplanned by the mine operators and become a concurrent part of the daily operation of the mine.[16] Segregation of the various strata in overburden removal is critical so that inferior spoil can be buried under clean fill, with topsoil returned to the surface to ensure successful revegetation.

This practice of continuous reclamation has already been introduced in the discussion on the earth-moving aspects of overburden removal. In area strip mining, draglines fill mined strips with overburden removed from succeeding strips and topsoil is placed on top to prevent rehandling. In contour mining, the reclamation follows a pattern of grading and backfilling the bench between the highwall and downslope. In this type of surface mining, the topsoil can be stockpiled for a limited time and replaced after the mining and grading have been completed. In contour mining by the block-cut method, topsoil is removed and placed on graded areas in a single operation.

Success in reclaiming mined land is determined to a large extent by geographic location and climatic conditions. Each location has its own inherent problems to be dealt with if an area is to be returned to the original topography. In contour mining operations in the East, careful practices of grading and backfilling can return natural drainage patterns and contour to the land. Use of trees alone to revegetate these areas was found to be unsatisfactory, because of the length of time required for the trees to establish themselves and the loss of soil by erosion in the interim. Presently, herbaceous species are preferred to stabilize the land rapidly; and plant covers suitable to the area are selected to control erosion, siltation, dust, and acid formation. In addition, seeding is no longer limited to the spring. Selecting species appropriate to the season when planting is needed and following with a perennial species in the spring or fall provide the optimum condition for revegetation. In the Eastern states, as well as those Central states where contour mining is used, a period of 2 to 3 years is required to reach this condition.[9]

Area mining is practiced in Florida, where phosphate rock is mined. Draglines strip overburden and fill the previous strip with this material in a single operation. The overburden is approximately 6 m (20 ft) deep, with phosphate deposits of some 5 m (16 ft) lying below. Land reclamation generally results in an area being filled and then graded to a level somewhat less than the original topography. Since the water table is comparatively close to the surface, these depressions usually create lakes, but the process is completed and the area stabilized in 1 to 2 years.[26]

Area mine reclamation in Midwestern states poses the fewest reclamation problems. These lands can be returned to their original topography by spoil segregation, backfilling, and grading as deposits are removed. Compaction of the soil can be controlled with conventional equipment, and this ground preparation for revegetation is aided by a climate that provides sufficient annual precipitation.

Reclamation in the West is another matter. Here the seam thickness of deposits mined is much greater and the original elevation cannot be restored. If a pattern of continuous reclamation is used at these mines, the overburden is deposited by draglines parallel to the strip being mined; smaller draglines or bulldozers then level these deposits to reduce slopes. This returns the area to a topography that will meet proper conditions for land stability, drainage control, and maintenance of vegetation. A recently regraded area is shown in Figure 14. The process of reestablishment is estimated to require a minimum of 5 years. Because of the arid or semiarid climate, successful reclamation to native climax vegetation is questionable. The extreme climatic conditions, with a seasonal variation of -50 to 50°C (-60 to 120°F) and an annual precipitation of less than 50 cm (20 in) over 65 percent of the area, create a soil with a highly saline condition that contributes to a lack of adequate topsoil. Wind also erodes this unprotected soil, adding to the problems of reestablishment. It is possible to regrade this disturbed land, but knowledge for successful seeding and procedures for revegetating the area are not yet adequate. In certain areas, such as the rimrock country in eastern Montana, it has been recommended that no mining be permitted in certain

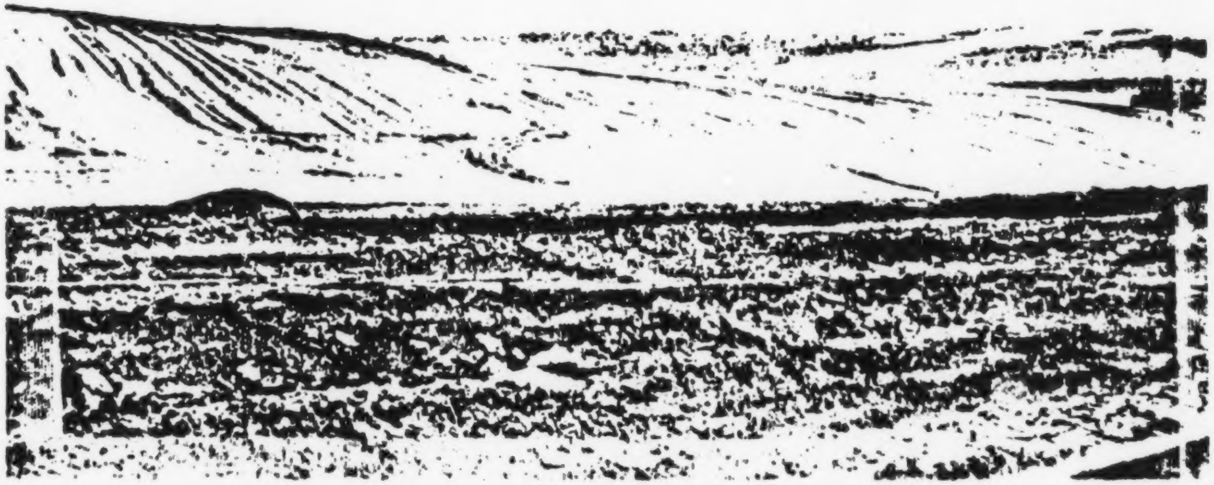


Figure 14. Reclamation.

deposits. Here it would be impossible to restore the original drainage patterns and slopes.

The amount of soil loss due to wind erosion of the barren land prior to revegetation is a function of the surface soil type, roughness of the surface, wind speed, average surface moisture content, and unsheltered distance across the regraded area. Obviously, the total wind erosion losses from a reclaimed area are directly proportional to the length of time involved in establishing protective vegetation on the surface. Although these wind erosion losses are low level except during wind storms, they occur fairly continuously over the entire reclamation area.

Emission Estimate--

When continuous reclamation is practiced, earth moving by dragline and scrapers produces a large amount of fugitive dust; however, these emissions are already included as part of the overburden removal operation. If the topsoil is stored and later redistributed or if a smaller dragline or bulldozer is used to grade the spoils area before applying the topsoil layer, emissions from these activities can be estimated with the same emission factors as applied to overburden removal.

All other emissions associated with the reclamation operation are due to wind erosion over the unreclaimed or partially reclaimed land. The U.S. Department of Agriculture's wind erosion equation has been used in several recent studies to estimate emissions from wind erosion across cleared or unprotected soil surfaces. The wind erosion equation was originally developed to estimate soil losses from cropland, but has been adapted to predict the suspended particulate fraction of total soil losses and has been applied to evaluate exposed soil surfaces other than cropland.[12]

The modified wind erosion equation is as follows:

$$E = a\ I\ K\ C\ L'\ V' \qquad \text{(eq.2)}$$

where E = emission factor, ton/acre/yr

a = portion of total wind erosion losses that would be measured as suspended particulate

I = soil erodibility, ton/acre/yr

K = surface roughness factor

C = climatic factor

L' = unsheltered field width factor

V' = vegetative cover factor

In this equation, K, C, L', and V' are all dimensionless.

Some recent work has indicated that the variable "a," as well as I, is related to soil type.[27] Values for "a" and I that might be applied to surface-mined areas during or following regrading are summarized below:

Surface soil type	a	I, ton/acre/yr (uncontrolled)
Rocky, gravelly	0.025	38
Sandy	0.010	134
Fine	0.041	52
Clay loam	0.025	47

Values of K can vary between 0.5 and 1.0, with 0.5 denoting a surface with deep furrows and ridges, which protect against wind erosion, and 1.0 denoting a smooth erodible surface. Unless the surface of a regraded spoil area has been plowed or roughened, a K factor of 1.0 should be used in the wind erosion equation.

Climatic factors (C) for use in the equation have been determined for most parts of the country by USDA, as shown in Figure 15 (the values in the figure should be multiplied by 0.01). For exposed areas greater than about 610 m (2000 ft) wide, the field width (L) no longer effects the emission rate and L' = 1.0. For smaller reclamation areas in irregular terrain where the field width is only about 305 m (1000 ft), the L' value

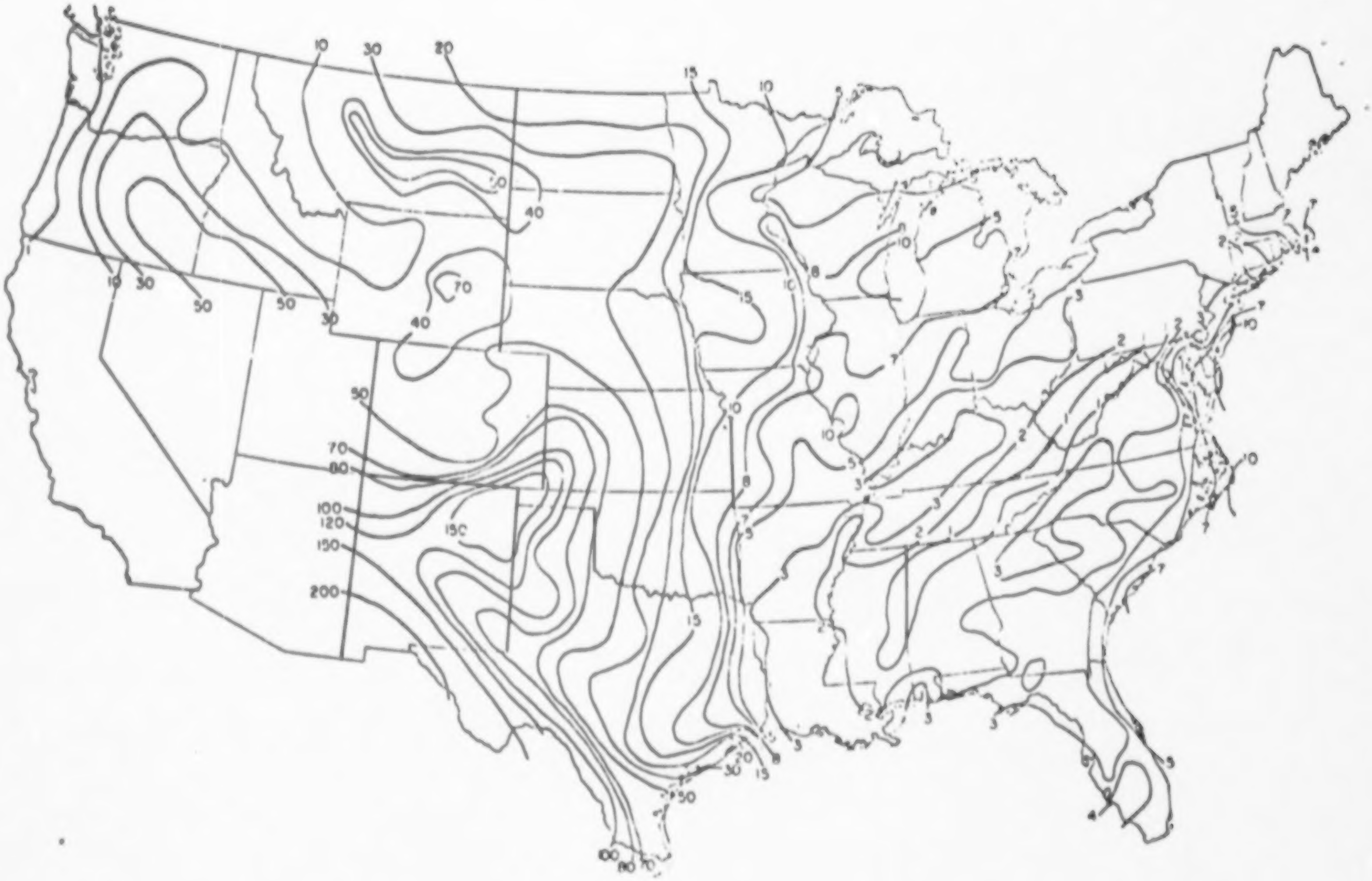

10
30
20
15
10
10
30
50
50
30
70
40
50
70
80
100
120
150
200
150
15
15
10
10
8
5
3
2
30
20
15
50
100
80
70
10
7
4

Figure 15. Climatic factors for use in the wind erosion equation.
Source: Armbrust, D.V., and N.P. Woodruff, 1968.

is approximately 0.7. Because recently regraded surfaces have little or no vegetation, V' in the equation is almost always 1.0.

By substituting the appropriate data into the wind erosion equation, the annual emission rate for any specific situation can be calculated. This estimated emission rate (E) is then multiplied by the number of barren acres at the mine during a particular year to determine total fugitive dust due to wind erosion. For a more detailed explanation of the modified wind erosion equation, see Appendix A of Development of Emission Factors for Fugitive Dust Sources.[12]

This method of estimating wind erosion emissions is acknowledged to have limited accuracy, but no other method has been proposed. All efforts to quantify wind erosion emissions that were found in the literature used some published USDA data on annual soil losses per acre as their basis. Because the wind-erosion emission rates per time unit are very low and highly variable, it is not possible to check the accuracy of the estimates by comparison with source sampling results.

SUMMARY OF MAJOR SOURCES AND EMISSION RATES

Eleven different mining operations were evaluated to establish their potential as fugitive dust sources. Emission rates from these operations vary by mine and by mining industry.

Estimates of emissions from the eleven mining operations are summarized in Table 6. These estimates should be used only after reviewing the descriptions presented earlier relevant to their development and applicability. From these emission estimates and typical production rates, the following approximate ranking of operations in order of decreasing emission rates can be determined:

1. Overburden removal
2. Haul roads
3. Reclamation
4. Storage
5. Shovels/Truck loading
6. Transfer and conveying
7. Truck dumping
8. Blasting

Table 6. SUMMARY OF EMISSION FACTORS FOR MINING OPERATIONS

Operation	No. of emission estimates	Range of uncontrolled emission factors	Emission factors by industry				More data needed
			Coal	Copper	Rock	P_2O_5 rock	
Overburden removal	5	0.0004-0.21 kg/Mg of ore (0.0008-0.45 lb/ton of ore)		0.0004 (0.0008)			x
		0.024-0.05 kg/Mg of over-burden) (0.048-0.10 lb/ton of overburden	0.025 (0.05)				
Blasting	2	0.0005-0.08 kg/Mg of ore (0.001-0.16 lb/ton of ore)					x
Shovels/Truck loading	5	neg-0.05 kg/Mg of ore (neg-0.10 lb/ton of ore)	0.025 (0.05)	0.025 (0.05	0.025 (0.05)	NA	
Haul Roads	4	0.6-1.6 kg/VKT) (0.8-2.2 lb/VMT)	depends on speeds and controls				x
Truck dumping	3	0.00017-0.02 kg/Mg of ore (0.00034-0.04 lb/ton of ore)	0.01 (0.02)	0.01 (0.02)	0.02 (0.04)	NA	
Crushing	4	neg-0.35 kg/Mg of ore (neg-0.7 lb/ton or ore)	neg		0.022 (0.044)		x
Transfer & conveying	5	neg-0.1 kg/Mg of ore (neg-0.2 lb/ton of ore)				0.07 (0.15)	x
Cleaning	0	Usually negligible		neg		neg	
Storage	5	.01175-0.21 kg/Mr (0.0235-0.42 lb/ton of ore)	0.054 (0.027)	0.33 (0.165)	0.33 (0.165)	0.20 (0.10)	
		3.9-14.8 kg/hectare/day (3.5-13.2 lb/acre/day)		1.9 (10.4)			
Waste	1	neg-32.2 Mg/hectare/yr (neg-14.4 ton/acre/yr)					
Reclamation	1	Use wind erosion equation Mg/hectare/yr(ton/acre/yr)	Depends on climate and soil				x

NA = not applicable

9. Crushing
10. Waste disposal
11. Cleaning

Overburden removal is much more of a dust problem at surface coal mines and phosphate rock mines than at copper mines and rock quarries because of the greater amounts of overburden material handled in the former mines. Fugitive dust from reclamation is also associated primarily with coal mining and phosphate rock mining and results from regrading of the spoils and wind erosion across the regraded surfaces. Haul roads are a major dust source at almost all mines, even though they normally are kept watered. The remaining operations generate dust through the handling or processing of the material being mined. Because of this, emission rates from most of them are highly dependent on the characteristics of the material as mined, i.e., moisture content, amount of fines, hardness.

Some of the operations create dust only in a few instances, such as copper tailings as a waste disposal source or air blowing as a cleaning process for coal. Waste disposal and cleaning operations generally are not significant fugitive dust sources at mines.

To estimate the fugitive dust emissions that stay suspended, an attempt has been made to express the emission factors in terms of the fraction less than 30 microns diameter whenever possible. Since data were not available to do this in all cases, some of the reported emission estimates may overstate the impact of those operations on a regional scale.

Table 6 also notes those operations for which more sampling or emission data are needed before reliable emission factors can be developed. More than half the operations, including those indicated to be the three largest sources at mines, are on this list. Many of these operations have not been sampled previously because of extreme difficulties in defining a representative process for sampling or because of special technical problems such as those encountered with measuring blasting or wind erosion emissions.

The air quality impact of fugitive dust from a specific mining industry is a function of the number of mines and the population exposed to their emissions. The number of coal mines is relatively large. The dusty Western surface mines are in remote locations, but the Midwest surface mines, although less dusty, are often in areas of moderate population density. There are relatively few copper mines and these are in isolated locations except for the mines near Tucson, Salt Lake City, and Butte. Fugitive dust from mining is shown to cause increased urban particulate concentrations in all three of these cities. Stone quarries account for the most mining sites, and they are often located near urban areas to reduce transportation costs. Phosphate rock is produced from relatively few mines, mainly in a limited area of west central Florida. Except in the cities of Lakeland and Winter Haven, population exposure to these mining emissions is low.

The air quality impact of mining emissions is attenuated by two additional factors. At many of the larger mines, the dust-producing activities occur in a pit that is considerably below surrounding ground level. Emissions from a depressed level have a lesser impact on ambient concentrations than the same emissions would have from ground-level or elevated sources. At other large mines, the mine property extends for many miles in all directions from the points of emission origin so that concentrations may be negligible by the time the dust plume crosses a property line.

REFERENCES - SECTION 2

1. Fugitive Dust from Mining Operations, Final Report, Task No. 6. Monsanto Research Corporation, Dayton, Ohio. Prepared for U.S. Environmental Protection Agency, Research Triangle Park, North Carolina. May 1975.

2. Mineral Industry Surveys, Coal--Bituminous and Lignite in 1974. U.S. Department of the Interior, Bureau of Mines, Washington, D.C. 1976.

3. Mineral Industry Surveys, Copper Production in December 1975. U.S. Department of the Interior, Bureau of Mines, Washington, D.C. 1976.

4. Mineral Industry Surveys, Stone in 1974. U.S. Department of the Interior, Bureau of Mines, Washington, D.C. 1975.

5. Mineral Industry Surveys, Phosphate Book, 1975. U.S. Department of the Interior, Bureau of Mines, Washington, D.C. 1976.

6. Phosphate Rock. Bureau of Mines Preprint from Bulletin 667, U.S. Department of the Interior, Washington, D.C. 1975.

7. Coal Surface Mining and Reclamation. Council on Environmental Quality, Washington, D.C. Prepared for Committee on Interior and Insular Affairs, United States Senate. March 1973.

8. Air Pollutant Emissions in the Northwest Colorado Coal Development Area. Environmental Research and Technology, Westlake Village, California. 1975.

9. Environmental Impacts, Efficiency, and Cost of Energy Supply and End Use. Volume 1. Hittman Associates, Incorporated, Columbia, Maryland. Prepared for Council on Environmental Quality, National Science Foundation, and U.S. Environmental Protection Agency. November 1974.

10. Energy Alternatives: A Comparative Analysis. University of Oklahoma, Norman, Oklahoma. Prepared for Council on Environmental Quality, Energy Research and Development Administration, U.S. Environmental Protection Agency, Federal Energy Administration, Federal Power Commission, U.S. Department of the Interior, and National Science Foundation. May 1975.

11. Environmental Impact Statement for Northwest Colorado Coal Development. U.S. Department of the Interior, Bureau of Land Management, Denver, Colorado. Unpublished.

12. Development of Emission Factors for Fugitive Dust Sources. U.S. Environmental Protection Agency, Research Triangle Park, North Carolina. Publication Number EPA-450/3-74-037. June 1974.

13. Emission Estimates for the Berkeley Pit Operations of Anaconda Company. PEDCo-Environmental Specialists, Inc., Cincinnati, Ohio. Prepared for Montana Air Quality Bureau, Helena, Montana. September 1975.

14. Chalekode, P. K., and J. A. Peters. Assessment of Open Sources. Monsanto Research Corporation, Dayton, Ohio. (Presented as Third National Conference on Energy and the Environment. College Corner, Ohio. October 1, 1975.) 9p.

15. Telephone call to Frederick Renninger. National Crushed Stone Association, Washington, D.C. March 18, 1976.

16. Environmental Protection in Surface Mining of Coal. U.S. Environmental Protection Agency, Cincinnati, Ohio. Publication Number EPA-670/2-74-093. October 1974.

17. Investigation of Fugitive Dust--Sources, Emissions, and Control. U.S. Environmental Protection Agency, Research Triangle Park, North Carolina, Publication Number EPA-450/3-74-036. 1974.

18. Supplement No. 5 for Compilation of Air Pollutant Emission Factors. Second Edition. U.S. Environmental Protection Agency, Research Triangle Park, North Carolina. April 1975.

19. O'Boyle, Charles J. Report of Inspection of the Berkeley Pit Mining and Primary Crushing Operations on July 2, 1975. U.S. Environmental Protection Agency, Denver, Colorado. August 1975.

20. Compilation of Air Pollutant Emission Factors. Second Edition. U.S. Environmental Protection Agency, Research Triangle Park, North Carolina. Publication Number AP-42. March 1975.

21. Air Emission Sources from a Lurgi Dry-Ash Gasification Facility Using Lignite Coal. IN: North Dakota Air Quality Maintenance Area Analysis. Appendix B. PEDCo-Environmental Specialists, Inc., Cincinnati, Ohio. Prepared for U.S. Environmental Protection Agency, Denver, Colorado. March 1976.

22. Coal Data. 1974 Edition. National Coal Association, Washington, D.C. 1975

23. Fugitive Dust from Mining Operations--Appendix, Final Report, Task No. 10. Monsanto Research Corporation, Dayton, Ohio. Prepared for U.S. Environmental Protection Agency, Research Triangle Park, North Carolina. May 1975.

24. Perry, John H. Chemical Engineer's Handbook. Fourth Edition. McGraw-Hill, Incorporated, New York, 1963.

25. Woodruff, N.P., and F. W. Siddoway. A Wind Erosion Equation. Soil Science Society of America Proceedings. 29:5. September 1965.

26. Particulate and Sulfur Dioxide Area Source Emission Inventory for Duval, Hillsborough, Pinellas, and Polk Counties, Florida. PEDCo-Environmental Specialists, Inc., Cincinnati, Ohio. Prepared for U.S. Environmental Protection Agency, Atlanta, Georgia. June 1975.

27. Nevada Particulate Control Study for Air Quality Maintenance Areas. Task B Report: Factors Influencing Emissions from Fugitive Sources. PEDCo-Environmental Specialists, Inc., Cincinnati, Ohio. Prepared for U.S. Environmental Protection Agency, San Francisco, California. January 1976.

SECTION 3

REGULATORY POLICIES

Regulatory policies for the specific control of fugitive dust from mining sources are practically nonexistent. State Implementation Plans (SIP's) in most states contain very general fugitive dust emissions regulations, which are often difficult to enforce, whereas some states have no regulations whatever for fugitive dust control. The Mining Enforcement and Safety Administration (MESA) indirectly regulates fugitive dust emissions through enforcement of personal respirable dust exposure standards. Mining safety and reclamation laws in some states also indirectly provide fugitive dust control through their overall safety and erosion prevention measures.

STATE AIR POLLUTION REGULATIONS

Fugitive emissions from mines and other sources cannot be easily measured to provide control officials with estimates of the relative magnitude of these emissions; therefore, the potential improvement in air quality that may result from control of these sources cannot be easily estimated. This deficiency is the major reason why little attention has been given to fugitive emission sources.

Source emission inventories included few fugitive emission sources, primarily because of the magnitude of stack emissions from poorly controlled sources (i.e., emissions from stacks of power plants and other industrial sources), but also because of estimates of emissions from fugitive emission sources were not available. Hence, the emission control regulations that were ultimately adopted by the State and local air pollution control agencies primarily addressed control of nonfugitive emission sources. Therefore, the mass emission limitations (i.e., those that limit emissions to "no more than X pounds per hour") adopted by States are not directly applicable to fugitive emission sources because compliance with such regulations can only be determined by measuring the total emissions from a process, generally through a stack. As previously indicated, this is extremely difficult for process sources with fugitive emissions. In cases where fugitive emissions can be measured, it is generally too expensive for source operators to rely upon the measurement technique to determine source compliance.[1]

Some states, however, have adopted general regulations to address the fugitive emissions problem. Of the four general regulatory techniques that have been used to control fugitive emissions, two are of limited value. The first of these involves the general nuisance provision that most pollution control agencies have included within their regulatory scheme. Under this provision, emissions from a source are prohibited if they affect any person's health or welfare. Nuisance regulations can be useful if the responsible sources can be specifically identified and are agreeable to reducing emissions. However, comprehensive source emission control programs rarely result from action taken under nuisance regulations. The second regulatory approach of limited value requires that source operations with fugitive emissions take "reasonable precautions to prevent fugitive emissions from becoming airborne." These regulations are generally difficult to enforce because "reasonable precautions" are not specifically defined.

The difficulties associated with the two regulatory approaches described have led to the development of a third and more successful approach to regulating fugitive emissions--a requirement that the source operator install, operate, and maintain specified equipment to capture and control fugitive emissions to prevent their becoming airborne. "Equipment standards," as they are termed, are enforceable and are believed to be effective for semiconfined control of many fugitive dust sources. This type of regulation, however, is not generally applicable to widespread mining sources.

The fourth regulatory technique is the visible emissions regulation. Such regulations generally prohibit the presence of visible emissions beyond the source's property line. With the exception of rock quarries located in or near population centers, this type of regulation is not usually amenable to mining sources because mines typically are situated in expansive and remote areas.

The Missouri Air Conservation Commission's fugitive dust regulation prohibits fugitive dust or particles larger than 40 microns beyond the source's property line. To establish the origin of the particles, the Commission employs microscopy to "fingerprint" the fugitive dust particles from samples taken adjacent to the source's property line, i.e., these sample particles are compared under the microscope with dust taken from potential source/s to identify their origin. This approach to regulation enforcement has been implemented at rock quarries, grain mills, and similar fugitive dust sources.

Table 7 presents a nationwide summary of particulate ambient air quality standards and fugitive dust regulations by state.[2] None of these regulations specifically apply to fugitive dust from mining sources.

MESA REGULATIONS

Dust regulations enforced by the Mining Enforcement and Safety Administration of the Department of the Interior are designed to protect the mine worker from exposure to hazardous dust concentrations. The regulations are primarily applicable to underground mines, where the confined atmosphere tends to concentrate the dust generated; however, because dust emissions from the surface mining activities are excessive at times, they

Table 7. SUMMARY OF STATE AMBIENT AIR QUALITY STANDARDS AND FUGITIVE DUST REGULATIONS

Jurisdiction	Primary Standard	Secondary Standard	Fugitive Dust and Dustfall
Alabama	Federal (75 $\mu g/m^3$ annual geometric mean of 24-hr concentration)	Federal (60 $\mu g/m^3$ annual geometric mean of 24-hr concentration)	No fugitive dust beyond property line. Abatement: Reasonable precautions, plus first three paragraphs of Federal model.
Alaska	Federal	Federal	No visible dust past property line. Abatement: First three paragraphs of Federal model.
Arizona	Federal secondary	Air Quality Goal: 100 $\mu g/m^3$ maximum 24-hr average	Fugitive dust from hauling, handling, crushing,or conveying of materials must be controlled by reasonable means.
Arkansas	Federal	Federal	May not exceed 75 ug/m^3 for any 24-hr period or 150 ug/m^3 for any 30-minute period (measured on property and subtracting background). Abatement: Reasonable precautions. Dust fall: maximum 15 $tons/mile^2/month$. Particles larger than 60 microns may not exceed $120/cm^2/24$ hrs.
California	Nonvehicular standards and regulations are set by counties		Fugitive dust regulations are devised by each county. Those with applicable regulations call for "reasonable precautions."
Colorado	Federal	Federal	If emissions are judged by a panel to be "objectionable," may require use of "best practical method" of control. Controls must be applied during nonworking hours as required to control dust. No visible emissions may cross property line.
Connecticut	Federal	Federal	Reasonable precautions, plus Federal model, except paving of roads not required and agricultural operations need not suppress dust. No discharge beyond property line if: 1) visible near ground, 2) impinges on building or structure.

(continued)

Table 7 (continued).

Jurisdiction	Primary Standard	Secondary Standard	Fugitive Dust and Dustfall
Delaware	70 $\mu g/m^3$ annual geometric mean of 24-hr concentration. 200 $\mu g/m^3$ 24-hr average concentration, not to be exceeded more than once per year. 500 $\mu g/m^3$ 1-hour average.	Federal	Water, chemicals, or approved techniques must be used to control dust emissions during demolition, grading, land clearing, excavation, and use of unpaved roadways.
District of Columbia	Federal	Federal	Federal model, except that agricultural operations receive no specific mention.
Florida	Federal secondary, except in Dade, Broward, and Palm Beach Counties, where the following apply: 50 $\mu g/m^3$ annual geometric mean. 180 $\mu g/m^3$ maximum 24-hr concentration.		Fugitive dust in excess of process emissions rate is prohibited. Reasonable precautions to abate fugitive dust are required.
Georgia	Federal	Federal	Federal model
Hawaii	100 $\mu g/m^3$ during any 24 hrs. 55 $\mu g/m^3$ annual arithmetic mean during any 12-month period.		No visible dust past property line. Ground level concentration at a point selected by the Department may not exceed 150 $\mu g/m^3$ above background. Dust fall may not exceed 3.0 grams per square meter per 14 days. Abatement by Federal model, except that Director may determine that "best practical" measures are sufficient.
Idaho	Federal	Federal	"All reasonable precautions" plus Federal model.
Illinois	Federal, plus no degradation of regional air quality p[illegible]d.	Federal	No emissions larger than 40 microns mean diameter. No emissions beyond property line visible when looking toward zenith. Not applicable in winds greater than 25 mph.
Indiana	Federal	Federal	No visible dust over property line. May not exceed 166 percent of upwind values, nor more than 50 $\mu g/m^3$ at ground level above background more than 60 minutes.

(continued)

Table 7 (continued).

Jurisdiction	Primary Standard	Secondary Standard	Fugitive Dust and Dustfall
Iowa	Federal	Federal	No fugitive dust beyond property line. Federal model for abatement, except that no mention is made of agricultural dust suppression or paving of roads.
Kansas	Federal	Federal	Airborne particulates at ground level at property line may not equal 2.0 μg per cubic meter, above background, more than 10 min/hr.
Kentucky	Federal	Federal	No fugitive dust beyond property line, plus Federal model, except (1) no requirement that roads be paved, and (2) agricultural operations can create airborne dust if no nuisance created. Secondary dust fall standard: 15 ton/mi^2/month.
Louisiana	Federal	Federal	Dust fall: 20 tons/square mile/month Coefficient of haze: 0.6 coh/1000 lineal ft., annual geometric mean; 0.75 coh/1000 lineal ft., annual arithmetric mean; 1.50 coh/1000 lineal ft., 24-hr. average. Abatement by Federal model
Maine	100 μg/m^3 24-hr average, 50 μg/m^3 annual geometric mean of 24-hr averages.		
Maryland	Primary: lowest concentrations attainable by reasonably available control methods, but not to exceed concentrations set forth as "secondary standards."	Annual arithmetric average: "More adverse": Lower Limit Upper Limit Serious 65 μg/m^3 75 μg/m^3 75 μg/m^3 daily average, once per year: 140 μg/m^3 160 μg/m^3 160 μg/m^3 dustfall, mg/cm^2/mo 0.35 0.50 0.50	Federal abatement model, except no mention of agricultural operations.

(continued)

Reproduced from best available copy.

Table 7 (continued).

Jurisdiction	Primary Standard	Secondary Standard	Fugitive Dust and Dustfall
Massachusetts	Federal	Federal	Reasonable precautions required. Fugitive dust from process industries, from transport or handling of materials, or from construction use and maintenance of roads may not "contribute to a condition of air pollution."
Michigan	Federal	Federal	Treated as a nuisance. Area of cut and fill open at one time is limited.
Minnesota	Federal	Federal	"Avoidable amounts" of dust must not become airborne. Director may order reasonable measures to be taken, including paving and frequent cleaning of roads, application of dust-free surfaces, use of water, and maintenance of vegetative ground cover.
Mississippi	Federal	Federal	Fugitive particulate matter must not become airborne as a result of handling, storage, or transport of any material. Dust fall may not exceed background levels by 5.25 grams/m^2/month on adjacent property.
Missouri			Reasonable precautions required. No fugitive dust or particles larger than 40 microns permitted beyond property line. Concentrations at property line: Suspended particulates 80 μg/m^3 6-month geometric mean 200 μg/m^3 2-hr arithmetic mean, for no fewer than 5 samples per year.
Montana	Federal	Federal	Reasonable precautions must be taken; no "controllable" particulate matter may be emitted. Specific measures may be ordered by the Director.

(continued)

Table 7 (continued).

Jurisdiction	Primary Standard	Secondary Standard	Fugitive Dust and Dustfall
Nebraska	Federal	Federal	No visible dust may pass over property line. Measures to control fugitive dust may include paving, frequent cleaning of roads, application of dust free surface, planting and maintenance of vegetation cover.
Nevada	Federal	Federal	Reasonable precautions are required. No visible airborne dust may cross property line.
New Hampshire	Federal secondary		Roads, storage areas, etc. shall be controlled to confine dust.
New Jersey	Ambient air quality must be highest achievable at present state of the art, but in no case may it be worse than the Federal primary standard.	Federal	No standard or model.
New Mexico	*150 μg/m^3 24-hr average 110 μg/m^3 7-day average 90 μg/m^3 30-day average *60 μg/m^3 annual geometric mean		No standard or model.
New York	State includes four "levels" from Level I: sparse population, to Level IV: Metropolitan. Short-term (all levels) average 24-hr concentration shall not exceed 250 μg/m^3. Long term: during 12 months, 50 percent of 24-hr concentrations may not exceed: Level I: 55 μg/m^3 Level III: 65 μg/m^3 Level II: 65 μg/m^3 Level IV: 75 μg/m^3 and 84 percent of 24-hr values shall not exceed: Level I: 45 μg/m^3 Level III: 100 μg/m^3 Level II: 85 μg/m^3 Level IV: 110 μg/m^3		Dust fall: During any 12 months, 50 percent of 30-day values shall not exceed: (mg/cm^2/mo) Level I: 0.10 Level III: 0.40 Level II: 0.10 Level IV: 0.60 During any 12 months, 84 percent of 30-day values shall not exceed (mg/cm^2/mo): Level I: 0.45 Level III: 0.60 Level II: 0.45 Level IV: 0.90

* Together comprise Federal secondary.

(continued)

Table 7 (continued).

Reproduced from best available copy.

Jurisdiction	Primary Standard	Secondary Standard	Fugitive Dust and Dustfall
North Carolina	**Federal Secondary**		Asphalt plants must limit fugitive dust to stack outlet. Roads must be treated around plant. In road construction, use of dust control on haul roads and water sprays over crushers for stone and aggregate handling are required.
North Dakota	**Federal Secondary**		Dust fall: 15 tons/mi^2/mo, maximum 1-month arithmetic mean in residential areas. 30 tons mi^2/mo. applies to heavy industry areas. 0.4 coefficient of haze/1000 lineal feet, maximum annual geometric mean. "Reasonable precautions" plus Federal model.
Ohio	**Federal Secondary**		Reasonable precautions plus Federal model.
Oklahoma	**Federal**	**Federal**	Reasonable precautions to control fugitive dust are mandatory.
Oregon	**Highest and best technology must be applied. Standards measured at "primary stations:" 60 ug/m^3 annual geometric mean; 100 ug/m^3 24-hr concentration not to be exceeded by 15 percent of monthly samples; 150 ug/m^3 24-hr concentration.**		Abatement by Federal model, less mention of agricultural operations of paving roads. Stockpiles of materials should be enclosed where other means do not control dust.
Pennsylvania	**Federal**	**Federal**	Dust fall: annual average 0.8 mg/cm^2/mo. 10-day average 1.5 mg/cm^2/mo. In all roadwork and land clearing fugitive dust must be confined to property, and not exceed 150 particles per cubic centimeter at property line. Abatement by Federal model, except no call for hoods, fans, or covering of trucks.

(continued)

Table 7 (continued)

Jurisdiction	Primary Standard	Secondary Standard	Fugitive Dust and Dustfall
Puerto Rico	Federal	Federal	No fugitive dust in visible quantities may be permitted to cross property line. Abatement by Federal model.
Rhode Island	Federal	Federal	No emissions to air from handling, transportation or storage of materials. Abatement by reasonable precautions during construction.
South Carolina	60 ug/m^3 annual geometric mean 250 ug/m^3 24-hr average		Dust control measures must be used on premises and roads of mining, quarrying and other unenclosed operations.
South Dakota	Federal Secondary		
Tennessee	Federal	Federal	Visible dust emissions may not pass proper property line more than 5 min/hr or 20 min/day. Abatement by Federal model, first three paragraphs only.
Texas	Federal Emissions from any source may not exceed: 100 ug/m^3 average over 5 hrs. 200 ug/m^3 average over 3 hrs. 400 ug/m^3 average over 1 hr.	Federal	Materials-handling dust must be controlled by use of water or chemicals, use of hoods and fans, and covering or wetting truck-bed loads. During road construction, dust suppression is required on all haul roads.
Utah	Federal	Federal	
Vermont	45 ug/m^3 annual geometric average 125 ug/m^3 daily average		Reasonable precautions must be exercised in road construction activities.

(continued)

Table 7 (continued).

Jurisdiction	Primary Standard	Secondary Standard	Fugitive Dust and Dustfall
Virginia	Federal, except in National Capital Air Quality Control Region, where Federal secondary standards must be met.	Federal	Federal model, except control of agricultural emissions are not required.
Virgin Islands	Federal	Federal	All reasonable measures, including watering and coating of roads, must be used during road construction.
Washington	Federal Secondary		Reasonable precautions are required.
West Virginia	Federal	Federal	
Wisconsin	Federal	Federal	Abatement by Federal model.
Wyoming	Federal Secondary coh-0.4/1000 lineal ft. annual geometric mean		Dust fall: 5 gm/m^2/mo for any 30-day period in a residential area. 10 gm/m^2/mo for any 30-day period in an industrial area. Abatement by Federal model.

also are covered by the MESA regulations. The most significant aspect of these laws, which also indirectly regulate fugitive dust emissions, involves maintenance of the average concentration of respirable dust in the mine atmosphere below the threshold limit values (TLV) adopted by the American Conference of Governmental Industrial Hygienists (ACGIH) in their 1973 edition of "TLV's Threshold Limit Values for Chemical Substances in Workroom Air Adopted by ACGIH for 1973." For example, MESA enforces a coal mine respirable dust limit of 2.0 mg/m^3*, the TLV specified by ACGIH.

---

* 36CFR 12213, Mineral Resources - Dust Standards, Sec. 70.100 (b) June 29, 1971.

REFERENCES - SECTION 3

1. Lillis, E. J., and D. Young. EPA Looks at "Fugitive Emissions". JAPCA. 25:1015-1018. October 1975.

2. Effects of Air Pollution Regulations on Highway Construction and Maintenance. National Cooperative Highway Research Program, Transportation Research Board, National Research Council, Howard, Needles, Tammer and Bergendorf. June 1975.

SECTION 4

CONTROL METHODS

The applicability of the various methods for controlling fugitive dust emissions from individual mining operations has been discussed in Section 2 of this report. This section discusses each of these control methods and summarizes their efficiencies and costs.

Unlike methods for controlling particulate emissions from conventional stationary and mobile sources, those for controlling fugitive dust from mining operations have not been researched and developed appreciably; consequently, they are not extensively documented in the literature. Almost all of the fugitive dust controls identified in the literature and observed firsthand during mining operation visits in this and previous studies were applications of one or a combination of three basic techniques: watering, chemical stabilization, and reduction of surface wind speed across exposed sources.

WATERING

Watering generally requires a low first cost, but it also provides the most temporary dust control. Depending on the nature of the dust-producing activity, water may be an effective dust suppressant for only a few hours or for several days. In addition to the direct cohesive force of a film of moisture in holding surface particles together, watering is also effective in forming a thin surface crust that is more compact and mechanically stable than the material below and is less subject to dusting even after drying. However, this crust and its dust-reducing capability are easily destroyed by movement over the surface or by abrasion from loose particles blown across the surface. Therefore, watering must be repeated frequently to reform the moisture film or surface crust.

An in-depth discussion of the effect of surface soil moisture on soil erodibility can be found in U.S. Department of Agriculture (USDA) Technical Bulletin No. 1185, Soil Conditions That Influence Wind Erosion.[1]

It should be pointed out that fugitive dust problems from mining are most prevalent in areas where the arid climate creates a lack of natural surface moisture. As a corollary to this, water is not readily available in these areas as a resource for air pollution control.

Applicability

Watering in the mining industry is primarily employed to control dust emissions from haul roads. Watering also can be used to control dust emissions from overburden removal, crushing, storage, and waste disposal, but its use for these operations is not widespread.

Haul roads at mines are routinely watered for dust suppression during all periods when water on the road surface does not create a safety hazard (generally when temperatures are above freezing). Large tank trucks equipped with a pump and directional nozzles normally are used to spray the water on the road surface and adjacent shoulders and berms. Fixed pipeline spray systems have also been used on main haul roads that are relatively permanent. At some Western mines, runoff from haul roads is diverted to settling ponds placed at intervals along the roadway.

If the use of water can be tolerated, it can be sprayed at crusher and shaker screen locations to keep the material moist at all stages of processing. However, the addition of water may cause blinding of the finest size screens, thereby reducing their capacity.

Watering alone is seldom used to suppress dust from overburden removal, storage, and waste disposal operations because of the vast area and quantities of material involved and because of the logistics and related costs of supplying the required amounts of water to the remote areas where these operations are usually located. The use of watering to control dust emissions from overburden removal is also hampered by the continuous exposure of dry material surfaces associated with this operation. Mining companies and the Bureau of Mines' Salt Lake City Metallurgy Research Center have done much research on the stabilization of waste tailings to prevent air and water pollution. Radically different methods -- chemical, physical, and vegetative -- have been tested, often successfully, on inactive tailings piles. Active tailings from new deposits generally have a moist surface and therefore are not susceptible to wind erosion.

The effect of watering on dust emissions from storage piles and surrounding areas at mine sites is quite temporary because continuous turnover of the material exposes new surfaces to wind erosion. Watering sometimes makes the material more difficult to handle. Also, enforcing watering regulations for this type of source is not an easy task.

A planned Bureau of Mines research project,[2] discussed in detail in Section 6, will evaluate the effect of water infusion of coal beds on respirable dust during mining operations.

CHEMICAL STABILIZATION

Several types of chemicals have been found effective in reducing dusting when applied on mining fugitive dust sources. These chemicals utilize different properties for dust suppression and are generally categorized by their composition -- bituminous, polymer, resin, enzymatic, emulsion, surface-active agent, ligninsulfonate, latex, etc. It is estimated that over 100 chemical products are presently marketed or are under development specifically as dust control agents.[3] Many of these are by-products or wastes from the production of other materials.

Available commercial products offer a wide range of characteristics making it possible to select a chemical stabilizer with maximum efficiency for each dust control application. Some of the materials "heal" if the treated surface is disturbed, but many do not reform. The life of the treated surface under natural weathering also varies widely with different chemicals. Selection of the appropriate material may require that several other criteria be checked for compatibility, including effect on vegetative germination and growth, method of application, possible contamination of material being protected from dusting, and correct chemical for the texture of a specific soil or material. Although no single comprehensive summary of dust suppressant chemicals and their properties was found, several evaluations have been prepared for different chemicals on a single type of fugitive dust source.

Applicability

Chemical stabilizers have been used to a limited extent to control dust from mining haul roads, storage piles, and inactive tailings piles.

Various chemicals may be added to the water or applied separately to the haul road surface to improve binding and reduce dusting. Application of a surface chemical treatment to suppress dust from haul roads is a relatively inexpensive control method. However, tests on public roads (conducted by several different highway departments) have failed to uncover any commercial material that retains its effectiveness over a reasonable period of time, i.e., 2 months under traffic conditions. Most of the treated surfaces abrade badly to the depth of penetration of the chemical (an important factor when considering the combined weight of the vehicles and loads trucking over these mining haul roads); others maintain a stabilized surface with traffic but are water-soluble and lose their effectiveness after rains. Several surface-treatment chemicals are presently under development or are being tested. Available technology for this method may increase greatly within the next few years.

A few successful special applications of surface treatment have been found. On nontraffic surfaces such as roadway shoulders, chemical soil stabilization has proven highly effective in reducing the dust produced by air turbulence from passing vehicles; however, this type of control would not be very effective for haul road berm stabilization because these berms are continuously disturbed by the passing trucks.

Another chemical dust suppressant method involves working the stabilization chemical into the roadbed to a depth of 5 to 15 cm (2 to 6 inches). This construction technique has been used extensively on rural unpaved roads in parts of the country where locally available petroleum by-products provide a cheap material for oiled earth roads. Many highway departments are testing this type of road to reduce dust problems. Few mining operations have applied this technique to mining haul roads, however. Actual paving of haul roads with a bituminous material has also found limited application and is restricted economically to permanent haul roads. Reportedly, paved haul roads produce a savings in haul truck tire wear in addition to controlling dust.

Chemical stabilizers react with dry inactive tailings piles in the same manner they react with soils to form a wind-resistant crust or surface layer. Of 65 chemicals for which test results have been recorded, the resinous, polymer, ligninsulfonate, bituminous base, wax, tar, and pitch products have proven most successful in stabilizing mineral wastes.[4] Most of the chemicals have demonstrated a long-term effectiveness in this application. Application can be accomplished by truck, piping spray systems, or plane--405 hectares (1000 acres) of the inactive Kennecott copper tailings area west of Salt Lake City have been successfully stabilized by aerial application of chemicals.

Recently, several tailings piles have been successfully planted by use of a combination chemical-vegetative technique.

The chemical stabilizers alleviate the problems of sandblasting and highly reflective surfaces and hold more water near the surface of the otherwise porous tailings, thus creating a more favorable environment for vegetation growth. Chemicals that do not have an inhibitory effect on the plants are selected for this purpose.

An effective, long-lasting method of controlling dust from storage piles is the addition of chemicals to the water sprays. Rather than acting as chemical soil stabilizers to increase cohesion between particles, most of these chemicals work as wetting agents to provide better wetting of fines and longer retention of the moisture film. Some of these materials remain effective without rewatering on piles stored for weeks or months. The system of application can be a continuous spray onto the material during processing or a water truck with hose and spray nozzle. The limiting factor here is the possibility of contaminating the stored material with the chemical dust suppressant.

REDUCTION OF WIND SPEED

Wind can contribute significantly to all of the mining fugitive dust sources, both by erosion of the exposed surfaces of storage areas, tailings piles, and reclaimed areas and by direct transport of the dust generated by the other mining operations. Therefore, reduction of surface wind speed across the source is a logical means of reducing emissions. This takes such diverse forms as windbreaks, enclosures or coverings for the sources, and planting of tall grasses or grains on or adjacent to exposed surfaces. The vegetative techniques all need a soil that supports growth -- one containing nutrients, moisture, proper texture, and no phytotoxicants. These requirements, especially adequate moisture, often cannot be met in mining areas; therefore natural protection against wind erosion is not always achievable.

Applicability

The large size of most of the mining fugitive dust sources precludes consideration of the widespread use of enclosures or wind barriers, with the following exceptions: mats used for safety purposes during blasting at construction areas could be employed on a limited, site-specific basis to help retard dust transport during small blasts at mine sites adjacent to populated areas; silos and other enclosed storage facilities are sometimes employed for storage of relatively small quanitities of mined material; enclosed conveying systems with hooding connected to control devices such as scrubbers or baghouses have been used; and hooding also can be employed to control the fugitive dust from truck dumping, crushing, and cleaning operations. A natural wind barrier is usually created during overburden removal and shovel/truck loading because of the depressed location of these operations.

Reclamation of mined areas is both a source of and a control technique for fugitive dust, i.e. the short-term reclamation operations, that produce fugitive dust such as regrading and revegetation, are designed to ultimately result in an area that is stabilized and protected over the long term from the erosion mechanisms of wind and runoff. Reclamation processes were discussed in detail in Section 2 of this report.

Many materials have been tried for physical stabilization of fine tailings. The material most often used is rock and soil obtained from areas adjacent to the wastes to be covered. Soil provides an effective cover and a habitat for encroachment of local vegetation. However, it is not always available in areas contiguous to the tailings piles and, even where available, it may be too costly to apply. Crushed or granulated smelter slag, another waste product, has been used to stabilize tailings. Another physical method of control involves covering with bark or harrowing straw into the top few inches of tailings.

Successful vegetative stabilization produces a self-perpetuating ground cover or fosters entrapment and germination of native plant seeds that will grow without the need for irrigation or special care. Several mining companies have planted old tailings accumulations in efforts to achieve both wind erosion control and an attractive site. Resistance to vegetative growth was encountered in these efforts because of excessive salts and heavy metals in the tailings, windblown sands destroying the young plants, high temperatures, and lack of water on the tailings piles.

The effectiveness of vegetative cover in reducing windblown dust is dependent primarily on the density and type of vegetation that can be grown on the resistant tailings. In a recent study, Bureau of Mines researchers were able to grow wheat and other small grain at a density of 25.8 plants/m^2 (2.4 plants/ft^2) on tailings.[5] This is equivalent to 1100 to 1700 kg/hectare (1000 to 1500 lb per acre) of stubble. Substituted into the wind erosion equation with a soil type of sand, unridged surface, and an unsheltered length of 610 m (2000 feet), the above vegetative densities reduce calculated emissions by 50 to 80 percent. An average control of 65 percent is proposed, with possible modifications of this value based on the density of growth on the tailings.

CONTROL EFFICIENCIES AND COSTS

Estimated percent reductions achieved by the fugitive dust control techniques found to be effective for mining operations and their related costs are presented in Table 8.

Control efficiency references listed as "PEDCo Estimates" are based on observations during mine visits and/or conversation with mining personnel from both the private and governmental sectors.

It should be emphasized that each of the control methods has a wide range of efficiencies and costs rather than the single

Table 8. SUMMARY OF CONTROL EFFICIENCIES AND COSTS FOR MINING FUGITIVE DUST SOURCES

Source	Applicable Control Method/Comments	Control		Control cost		
		Estimated Efficiency, %	Reference	Unit Cost, $	Units	Reference
Overburden Removal	Watering/Rarely practiced	50	PEDCo Estimate	no data		
Blasting	Mats/Very rarely employed	no data		no data		
Shovels/Truck Loading	Watering/Rarely practiced	50	PEDCo Estimate	no data		
Haul Roads	Watering/By far the most widely practiced of all mining fugitive dust control methods	50	(6)	no data		
	Surface treatment with penetration chemicals/Employment of this method increasing	50	(6)	600-1900 (1000-3000)	km mile	Chemical Suppliers
	Paving/Limited practice	90-95	PEDCo Estimate	no data		
Truck Dumping	Watering/Rarely Practiced	50	PEDCo Estimate	no data		
	Ventilated enclosure to control device/Rarely employed	85-90	PEDCo Estimate	no data		
Crushing	Adding water to material to be crushed/Fairly commonly practiced	95	PEDCo Estimate	negligible		
Transfer and Conveying	Enclosed conveyors/Commonly employed	90-99	PEDCo Estimate	no data		
	Hooding with control devices at transfer points/Rarely employed	85-99 (depends on control devices)	Based on efficiency of applied control devices	no data		
Cleaning	Very little control needed since basically a wet process					
Storage	Continuous spray of chemical on material going to storage piles/ Rarely practiced	90	[illegible]	44-140 (20-50)	kg (lb)	(8) (9)
	Watering (sprinklers or trucks)/ Rarely practiced	50	PEDCo Estimate	no data		
Waste Disposal Tailings Piles	Chemical stabilization/ Limited practice	80	a	60-160 (150-400) 100-240 (250-600)	hectare (acre) hectare (acre)	(10) (11)
	Vegetation/Commonly practiced	65	Calculated from Wind Erosion Equation	80-180 200-450 (hydroseeding)	hectare (acre)	(11)
	Combined chemical-vegetative stabilization/Rarely employed	90	PEDCo Estimate	40-60 (100-150)	hectare (acre)	(8)
	Slag cover/Limited practice	95-99	PEDCo Estimate	140-180 (350-450)	hectare (acre)	(11)

a Similar to efficiency determined in a study of chemical stabilization of construction area costs and fills.

Reproduced from best available copy.

average value discussed here. Recent cost data represent total costs, including application. The source of the cost data is also identified. Numbers shown in the cost "Reference" column refer to publications from the reference list.

REFERENCES - SECTION 4

1. Chepil, W.S. Soil Conditions That Influence Wind Erosion. U.S. Department of Agricultural. Technical Bulletin No. 1185. 1958.

2. Evaluation of the Effect of Water Infusion of Coal Beds on Respirable Dust During Mining Operations. Bureau of Mines, RFP-J0366051. April 23, 1976.

3. Armbrust, D. V., and J. D. Dickerson. Temporary Wind Erosion Control Cost and Effectiveness of 34 Commercial Materials. J. Soil Water Conserv. 26 (4): 154-157. 1971.

4. Dean, K. C., and R. Havens. Stablilizing Mineral Wastes. Engineer Mining Journal, pp. 99-103 April 1971.

5. Dean, K. C., R. Havens, and K. T. Harper. Chemical and Vegetative Stabilization of a Nevada Copper Porphyry Mill Tailing. U.S. Department Interior, Bureau of Mines, RI 7261. May 1969.

6. Roberts, J. W., A. T. Rossano, P. T. Bosserman, G. C. Hofer, and H. A. Watters. The Measurement, Cost and Control of Traffic Dust and Gravel Roads in Seattle's Duwamish Valley. Paper No. AP-72-5 presented at the Annual Meeting of the Pacific Northwest International Section of the Air Pollution Control Association, Eugene, Oregon. November 1972.

7. Johnson - March Corporation. Chem-Jet Dust Suppression. Product Information Brochure CJ2 1963.

8. Dust Suppressant Clears the Air at General Crushed Stone Plant. Rock Products, p. 63 August 1971.

9. Witco Chemical. Coherex Manual for Dust Control. Product Information Manual. 1970.

10. Chemical Treatment of Waste Tailings Puts an End to Dust Storms. Engineer Mining Journal, pp. 104-105. April 1971.

11. Dean, K. C., and R. Havens. Reclamation of Mineral Milling Wastes. Presente at the Annual AIME Meeting, San Francisco, California. February 1972.

SECTION 5

MEASURING AND MONITORING TECHNIQUES

This section summarizes the state-of-the-art in ambient air monitoring of fugitive dust emissions sources. Preliminary monitoring to determine emission factors for surface mining operations has been accomplished.[1] This work, however, was not extensive and did not include specific monitoring of many of the sources characterized as being the most significant fugitive dust sources in the mining industry.

Although surface mining operations have not been monitored extensively, the techniques used to monitor other fugitive dust sources and consequently to derive emission factors for those sources apply also to monitoring mine operations.[2,3] The nature of the particulates and operations of most of the fugitive dust sources previously studied is similar to that of the sources in the mining industries.

Each fugitive dust source has special characteristics that influence: monitor siting, sampling schedule and technique, and choice of monitoring equipment. The following are some of the important source characteristics that may affect sampling schemes:

- Physical characteristics of the particles emitted
- Controls applied to the source
- Source activity levels
- Local meteorological conditions
- Proximity of sources within the industrial site boundaries
- Plume development and particle transport properties.

A previous study documented the relationships between these characteristics, the source type, and the sampling plan.[5] A comprehensive summary of techniques or guidelines for monitoring fugitive dust emissions is not available.

MONITOR SITING

Several monitors are required to adequately monitor fugitive dust emissions from surface mining sources. Work performed to date has been oriented toward development of emission factors and the collection of technical data necessary to characterize the plume development and particle transport properties of emissions from various fugitive dust sources. The quantitative estimation of the number and size of particles that are considered to be suspended particulates, i.e. those that do not settle within a short distance from the site, has been a primary goal of many of the emission factor studies. This is especially important because the suspended particle fraction includes the smaller particles (Average = 3.5 μm diameter) and these particles, being the respirable fraction, have the most direct impact on public health. Nothing has been published regarding work on the optimal placement of monitors throughout an area that includes surface mining operations. The techniques described here are summarized from previous studies, and they apply to monitoring individual sources.

Monitors are usually located along a line from the source in the mean wind direction. An upwind monitor generally is used to determine background concentrations from sources upwind of the primary source (the source being monitored).[1,5] One monitor is placed downwind and as near the primary source as possible without interferring with source activity, i.e. movement of equipment, etc. This monitor should receive the full impact of the source emissions, including the larger, settleable particulates. A second monitor should be placed downwind from and in line with the first monitor. This monitor should receive primarily the impact from the smaller particles, i.e. those that do not readily settle, and therefore provide the best estimate of the emissions from this source that will impact the ambient air quality. The distance of the site of this monitor, which is referred to as a boundary site, from the primary source can be determined by considering the source type. Several particle deposition rate studies[6] and correlations from emission factor work[3] are the best available sources for determining the optimal placement of the boundary site. Two or more additional boundary sites may be necessary to compensate for fluctuations in the wind direction component downwind from the source. These monitors are usually on a circle whose radius is the distance from the primary source and the first boundary site. In one study, a mathematical formula was applied to determine the placement of these additional boundary sites.[1] Increased sampler height may be substituted for distance at the boundary sites.[5]

Some sources, unpaved roads for example, may be treated as moving point sources that emit dust at a relatively constant rate during vehicle movements. Figure 16 shows the general movement of the dust plume from this type of source. The sampler must be placed at a sufficient distance from the source to allow the plume to develop adequately. Plume characteristics depend on vehicle speed.

Monitoring of individual static and mobile fugitive dust sources represents the work completed to date. Guidelines are not available to assist in determining the number of sites necessary, the height of the sampler above ground, or the source-sampler distance. A review of much of the previous work on fugitive dust emissions, however, can provide some general guidelines. A recent publication[6] provides guidance for monitoring industrial process fugitive particulates by three basic methods: quasi-stack sampling, roof monitor sampling, and upwind-downwind sampling. However, only the upwind-downwind technique has any application to mining processes.

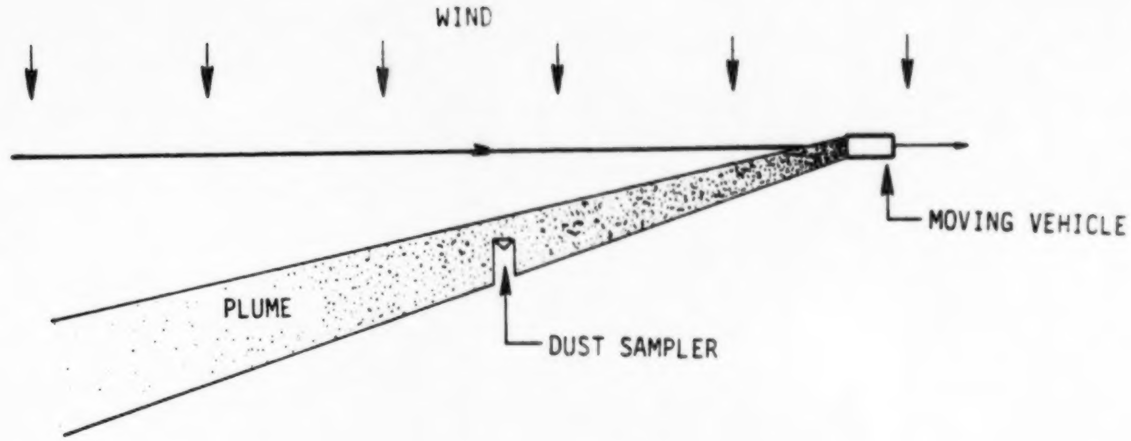

WIND
MOVING VEHICLE
PLUME
DUST SAMPLER

Figure 16. Overhead view of dust plume from moving point source.[3]

MONITORING EQUIPMENT

Fugitive dust studies have used five types of sampling equipment, most of which are adaptations of the high volume (hi vol) sampler: a hi vol, a wind-direction hi vol, a vertical profiler, a hi vol with Andersen modification, and a beta guage.

Hi-Vol Samplers

The hi-vol sampler is an apparatus for collecting a relatively large volume of air [1.5 to 2.0 cubic meters per minute (52 to 70 cfm)] and capturing its suspended particulate matter on a filter. The sampler consists of a motor-driven blower and a supporting screen for the filter ahead of the blower. During the sampling operation the sampler is supported in a protective housing so that the 20 x 25 cm (8 in x 10 in) surface of the filter is in a horizontal position. The sampler incorporates a continuous flow device for recording the actual air flow over the entire sampling period. A 7-day clock switch starts and stops the sampler.

The major limitation of the hi vol sampler is that it has a low efficiency when sampling large-diameter particles.[7] Consequently, it may be necessary to modify this sampler for selected source monitoring, e.g. soil or unpaved roads where the majority of the particles are large.

Wind-direction Hi-Vol

This is a standard hi vol activated by signals from a wind instrument. The sampling occurs only when the wind is in the predetermined direction. A recent development[8] has the potential of providing more comprehensive wind directional data than the conventional directional hi vol. This instrument, which is currently being tested, uses a standard hi vol sampler and collects samples on filter slides by drawing air through a porting arrangement activated by an associated wind vane. The instrument was developed specifically to collect data that would help identify major pollutant contributors.

Vertical Profiler

For one study a vertical profiling tower developed by Midwest Research Institute (MRI) was used to sample emissions from unpaved roads.[3] The profiler shown in Figure 17 is a vertical array of hi vol filtration devices attached to a mobile support tower. The intake area of each filtration unit is reduced to allow isokinetic sampling. A flexible hose 10 cm (4 in.) in diameter connects each sampler to a suction manifold. Each leg of the manifold is fitted with a calibrated orifice and a butterfly valve for flow control. The vacuum source is a 2-hp centrifugal blower. Electrical power is supplied by a gasoline engine generator.

Hi-Vol with Andersen Head Modification

The Andersen cascade impactor is designed to fit a standard hi vol. This modification of a standard hi vol sampler was developed to detect size distribution of total suspended particulates. It has five fiberglass impaction surfaces followed by a fiberglass back-up filter. The impactor design separates particulate matter into five aerodynamic size ranges: 7 μm or larger, 3.3 to 7 μm, 2.0 to 3.3 μm, 1.1 to 2.0 μm, and 0.01 to 1.1 μm. Although several types of cascade impactors are available, all of them do not produce comparable results.[9] The principle of impaction varies, as do the size ranges of the particles collected.

Beta Guage[9]

A beta guage sampler consists of a two-stage collection system for respirable dust measurements and a beta absorption unit. The first stage is a cyclone precollector for retention of the nonrespirable fraction of the dust, particles larger than about 10 μm in diameter. Particles not retained by the cyclone are collected by the second stage, which is a circular nozzle impactor-beta absorption assembly with an impaction disc. Particles collected by impaction on a plastic disc film increasingly absorb

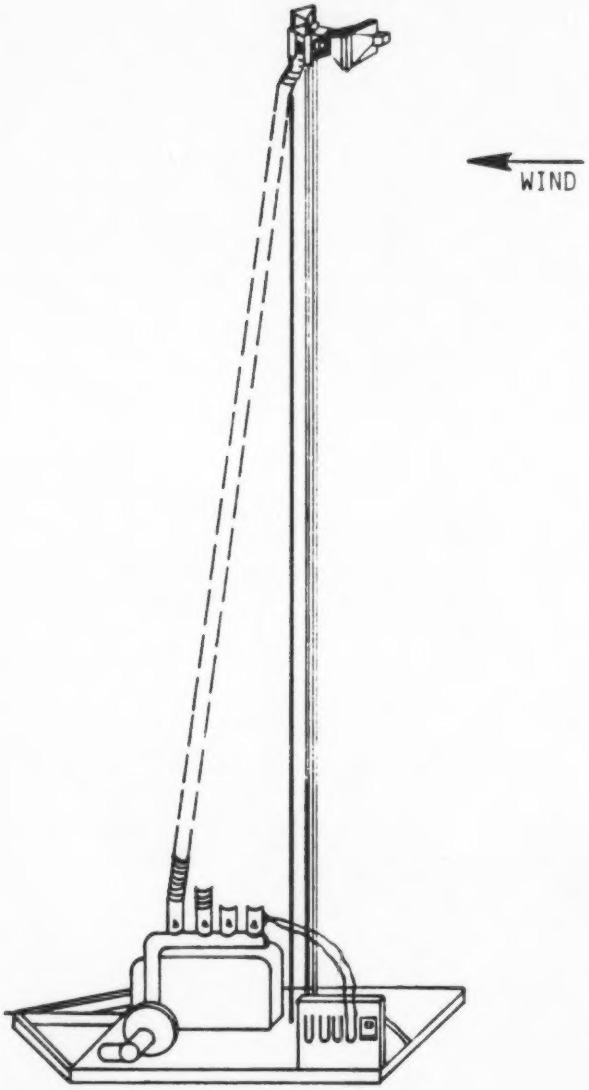


Figure 17. MRI vertical profiler.

beta radiation reaching a Geiger detector from a carbon-14 source. The penetration of beta radiation relates directly to the mass-per-unit area of the disc. Beta guages have been applied in sampling programs when short-term (i.e. a few minutes as opposed to several hours) measurements of respirable dust fractions were desirable.

SPECIAL CONSIDERATIONS

Monitoring fugitive dust sources like those identified in surface mining involves some special problems. These problems relate to the nature of the emission sources, to changes in source activity, and to variations in meteorological conditions and to the influence of these conditions on particle transport. No single publication summarizes the special problems associated with the fugitive dust sources that have been mentioned. Reports from individual source studies provide the best source of information.

Special problems associated with the nature of the emission sources can affect the sampling schedules, the choice of monitor for these sources, and the choice of monitoring site. The degree of control at the source may preclude the necessity to monitor the source. For example, experience shows that aggregate storage piles that are wet are not subject to wind erosion effects. Consequently, monitoring around wet storage piles is not needed. Experience also shows that loading and unloading operations are the major sources of emissions around storage piles. Thus, scheduling monitoring to include periods of reasonable activity is important.

Other sources, such as unpaved roads, might require isokinetic sampling to trap larger particles that might be missed by conventional hi vol methods. Sampling rates, sampling time, and wind speed are key factors in a case like this.

Data interpretation will be influenced by variables such as meteorological conditions. Wind erosion effects are influenced by wind speed, for example. In addition, wind direction and activities at other sources will influence monitoring results at a particular site. Rainfall and other precipitation also will alter the emissions from these sources, and time averaging may not be possible.

REFERENCES - SECTION 5

1. Blackwood, T.R., T.F. Boyle, T.L. Peltier, J.V. Pustinger, and D.L. Zanders. Fugitive Dust from Mining Operations - Appendix. U.S. Environmental Protection Agency. Raleigh, North Carolina. May 1975.

2. Cowherd, C., K. Axetell, C. Duenther, and G. A. Jutze. Development of Emission Factors for Fugitive Dust Sources. U.S. Environmental Protection Agency. Research Triangle Park, North Carolina. June 1974.

3. Jutze, G. A., and K. Axetell. Investigation of Fugitive Dust Volume I - Sources, Emissions, and Control. U.S. Environmental Protection Agency. Research Triangle Park, North Carolina. June 1974.

4. Lebowitz, M.F. Short-Term Testing for Fugitive Dust Effect. Allegheny County Bureau of Air Pollution Control. Presented at 68th Annual Meeting of the Air Pollution Control Association. Boston. June 15-20, 1975.

5. Kolnsberg, H.J. Technical Manual for the Measurement of Fugitive Emissions. U.S. Environmental Protection Agency, Contract 68-02-2110. Research Triangle Park, North Carolina. March 1976.

6. Sehinel, G. A. Experimental Measurements and Predictions of Particle Deposition and Resuspension Rates. Battelle, Pacific Northwest Laboratories. Presented at the 68th Annual Meeting of the Air Pollution Control Association. Boston. June 15-20, 1975.

7. Lundgren, D.A., and H.J. Paulus. The Mass Distribution of Large Atmospheric Particles. Presented at the 66th Annual Meeting of the Air Pollution Control Association. Chicago. June 24-28, 1973.

8. Deyo, J., J. Toma, and R.B. King. Development of a Portable Wind-Sensitive Directional Air Sampler. National Aeronautics and Space Administration, Cleveland. Presented at the 68th Annual Meeting of the Air Pollution Control Association. Boston. June 15-20, 1975.

9. Air Sampling Instruments. American Conference of Governmental Industrial Hygienists, Cincinnati, Ohio. 1972.

SECTION 6

HEALTH AND WELFARE EFFECTS

FUGITIVE DUST

The existence of fugitive dust has been known for some time, but its impact on air quality was not quantified until 1972. At that time, emission factors were developed which indicated that fugitive dust represents a significant portion of the total particulate matter emissions in some Southwestern Air Quality Control Regions (AQCR's). For example, it has been estimated that fugitive dust emissions in the Phoenix AQCR contribute approximately 90 percent of that region's total suspended particulate (TSP) emissions. Control strategies based upon emission inventories that include fugitive dust emissions indicate a need to pave unpaved roads and reduce windblown dust from exposed soil if material standards are to be attained. The latter might be accomplished by soil conservation measures or by soil stabilization that minimizes soil erosion (i.e., windblown emissions). These measures are in addition to the more traditional stationary source controls.

The specific health impact of fugitive dust on human health is generally unknown. No epidemiological studies have been conducted in areas where the TSP concentration is high because of fugitive dust. Specific information on the chemical makeup of TSP in these areas is not available; however, the toxic fraction of the TSP is very likely to be small. On the other hand, dust from unpaved roads may contain high concentrations of lead and other heavy metals from automobile exhaust. Further, windblown dust from farmlands may contain various pesticides and herbicides that are potentially toxic. Dust from tailings piles near smelters may also be high in heavy metals.

No information establishes that fugitive dust creates no health problems, nor does any information define a special particulate matter standard for these areas; therefore, the current national standard, though imperfect, provides the best available standard to protect public health. Hence attainment of the current national standard should be the goal in the fugitive dust area as well as elsewhere. It should be noted that any attempt to develop a new standard for any pollutant is a long-term project (i.e., 5 to 7 years); hence, such activity would not alleviate the current problems associated with fugitive dust. Currently, EPA is investigating the need for national standards to control various toxic components of TSP, such as sulfates and nitrates. This investigation may have some impact on approaches to TSP control in fugitive dust areas.

FUGITIVE DUST FROM MINING

The effects of the particulate emissions from surface mining fugitive dust sources may be similar to the effects of particulates from natural fugitive dust emission sources. Neither type of particulate matter has been studied extensively to characterize its impact on public health or welfare. Urban particulates have been studied more extensively, and correlations between ambient particulate concentrations and morbidity and mortality rates have led to the establishment of ambient air criteria.

In the case of some fugitive dust source types for which emission factors have been derived, particle size determinations were made as part of the emission testing studies. A significant portion of the emissions for these sources were determined to be in the size range of particles that are transported outside of the source boundaries. If the mining operations in an area are substantial, and other types of industry are medium or light in comparison, then the emissions from the mining operations might be expected to have a considerable impact on the local air quality. Thus, the respirable portion of those emissions would be expected to contribute to pulmonary problems among the local population. Directional sampling and tracer studies could provide the necessary data to determine the total particulate impact from mining on regional health and welfare.

SECTION 7

RESEARCH AND DEVELOPMENT PROGRAMS

This section presents brief descriptions of research and development programs (either ongoing or in planning stages) involving fugitive dust from mining. Information on these programs was obtained by contacting the various agencies concerned with mining activities--Bureau of Mines, Mining Enforcement and Safety Administration, various EPA laboratories, and others.

Open Source Assessment, part of EPA Contract 68-02-1874 with the Resources Extraction and Handling Division of the Industrial Environmental Research Laboratory/ Cincinnati, by Monsanto Research Corporation.

The objective of this project is to provide the data necessary for EPA to plan future action in developing control technology for open sources of emissions. Five major criteria are used to emphasize effects on public health. These are source severity, source contribution to national emissions burden, contribution to individual state's emissions burdens, population affected, and growth or decline of emissions from industries using current control technology. Open mining sources include sand and gravel, coal storage, clay mining, phosphate rock mining, open coal mining, crushed traprock and stone, crushed granite, crushed quartzite and refractory stone, crushed limestone, and coal refuse piles. Other sources may occur as a result of planned activities.

Quantification of Fugitive Process Emissions, EPA Contract, Office of Air Quality Planning and Standards, Environmental Protection Agency, Research Triangle Park, by PEDCo Environmental Inc.

EPA has issued a task order for approximately two man-years of effort to identify industries that emit a significant amount of fugitive dust in their processes (through roof vents, off conveyor belts, from material storage areas, from unhooded reaction vessels, etc.). The work plan has not yet been prepared but it is expected that several of the unit operations found in mines will be investigated as part of this study. However, no sampling will be conducted, and it is doubtful that information from the literature search will uncover any additional emission factors for mining operations beyond those given in the Task 1 report of this project. Emission data from similar processes used in other industries may be adapted for application to mining operations.

Water Infusion of Coalbeds, RFP No. J0366051, U.S. Bureau of Mines.

This study will evaluate the effect of water infusion of coalbeds on respirable dust generated during mining operations. Infusion work will be conducted on either development sections 150 m [less than (500 feet) wide] or longwalls. The study will cover the coalbeds in the Beckley, West Virginia, area.

Study to Develop Emission Factors for Surface Coal Mines, EPA Region VIII Energy Office.

Air Quality Maintenance Area (AQMA) analyses for several of the energy development areas in Region VIII showed that intensive coal mining has the potential of causing air quality standards to be exceeded in these areas. Therefore, the Region VIII Energy Office has allocated money to fund a project to sample particulate emissions at three different coal mines. The purpose of this sampling is to develop more accurate emission factors for mining operations than those currently available. The scope of work of this proposed contractual effort has been drafted and approved within EPA, but has not yet been released in the form of a (RFP). The probable approach to this project will be to locate a number of high volume samplers at varying distances downwind from the mining sources and one sampler upwind to establish background concentrations. Using Gaussian dispersion equations, the emission rates would then be calculated from the measured ambient loadings.

> Surface Environment and Mining (SEAM) Studies, by the Forest Service Intermountain Forest and Range Experiment Station, Ogden, Utah.

Three SEAM mining research studies are either under way or in the planning stage. EPA is funding selected portions of these studies, which are energy-related, through Subagreement 77BED. These studies are briefly described below:

> Methodology for Assessing the Environmental Impacts of Mining Roads and Road Construction on Water Quality, Hydrologic Effects, and Fugitive Dust, by grant to Montana State University.

The purpose of this currently active SEAM study is to identify and assess the environmental impacts of four mining-related transportation systems: haul roads, railroads, pipelines, and electrical transmission lines. This research effort has been reoriented to concentrate on the effects of roads and road construction on water resources and fugitive dust problems. The study will identify characteristics of the road system and relate these to on-site data on climate, soils, topography, vegetation, etc. by means of mathematical relationships, whenever possible. These efforts will result in quantitative estimates of the impact of road construction on the quality, quantity, and peak flow of both ground water and surface water, and estimates of the amount of fugitive dust that may be expected.

> Impact Assessment of Roads on the Hydrologic Regimen of Streams, including Sediment Loads. In-house research effort by the Forest Service.

This proposed SEAM study would measure the effect of roads on the sediment loads, stream flow peaks, and channel stability of streams that cross haul roads (both off-site access roads and on-site mine roads). This effort would concentrate on the effect of roads because this is the most common transportation mode associated with coal and oil shale surface mining.

Determination of the Erodibility of Raw Spoils and Topsoil by Wind and Measurement of Fugitive Dust from Mining Roads, by grant to Montana State University.

This SEAM study is proposed in response to the interest of EPA in wind erosion of spoil and topsoil materials and in the fugitive dust problem from mining roads. Measurements will be taken of the erodibility of raw spoils and topsoil material subject to wind erosion. Measurements also will be made of the fugitive dust from mining roads.

Air Pollution Research in Western Surface Coal Mining Areas - planned project for the Resources Extraction and Handling Division of the Industrial Environmental Research Laboratory/Cincinnati, by Mathematica, Inc., with ambient sampling by Hittmann Associates.

This project will involve monitoring fugitive dust levels at four mines under varying climatic conditions. The results will be used to develop and validate mathematical models for estimating dust levels as a function of climatic, topographic, and geologic factors. Ambient dust levels in selected geographic areas will be compared with the dust levels in active surface mining areas, thereby determining the extent and magnitude of the fugitive dust conditions caused by mining. Effectiveness of dust control procedures now employed at active mines will be evaluated and new dust control procedures for surface mining operations will be recommended if needed. Analytical tools will be developed that can be used to estimate dust levels as a function of various physical factors.

Development of a Manual of Testing for Fugitive Dust Sources and Related Fugitive Dust Assessments, for EPA's Process Measurements Branch, Industrial Processes Division, Industrial Environmental Research Lab, Research Triangle Park, by the Research Corporation of New England.

This ongoing multimedia study will assess fugitive dust emissions from both process and open sources. The study, which will take 3 years, is budgeted at $250,000. A manual of testing methodology will be developed, including quasi-stack monitoring, roof monitoring, and upwind-downwind techniques. In addition, the feasibility of employing remote sensing techniques to replace upwind-downwind sampling will be explored in several source areas.

SECTION 8

RECOMMENDATIONS REGARDING ADDITIONAL RESEARCH AND DEVELOPMENT

This section recommends and discusses possible studies to provide needed data related to fugitive dust from mining sources. The recommendations were developed by analyzing current and planned research and development studies in light of emission data gaps, needed control technology, and present procedures for mining impact evaluation.

DEVELOPMENT OF CONTROL METHODOLOGY FOR MINING HAUL ROADS

Haul roads are common to all surface mines and consist mainly of temporary unpaved roads between active mining areas, tipple, waste disposal areas, and equipment service areas. In terms of total dust generated, they are the second most significant fugitive dust source in mining operations. They also are probably the most amenable to control. Watering is the predominant control method; however, the recent success of chemical stabilization technology indicates that the use of this method is likely to increase. Sections 2 and 4 provide detailed information on the emission characteristics of haul roads and the efficiencies of available control methods.

Comprehensive Assessment of Chemical Stabilization of Haul Roads

Various stabilizing chemicals may be used with water or applied separately to the haul road surface to improve binding and reduce dusting. It is estimated that over 100 chemical products are presently marketed or are under development specifically as dust control agents,[2] and most of these are suitable for application to haul roads. Although considerable information is available regarding the effectiveness of chemical suppressants in controlling dust from unpaved roads, a comprehensive comparison of the many chemicals available has not yet been compiled. Accordingly, it is recommended that a study be conducted to assess the effectiveness of chemical suppressants applied to haul roads. The study would consist primarily of acquisition and subsequent evaluation of all published results of research and development on chemical suppressants, plus contacts with mining companies, construction contractors, highway departments, and chemical suppressant vendors. A limited amount of field testing might be employed for further evaluation of the chemical products judged to be most effective.

Investigation of Methods of Stabilizing Haul Road Berms

Although no studies have been conducted to quantify the fugitive dust emissions from haul road shoulders, observations made during this study indicate that considerable dust is emitted from this source. Generally, minimal dust was observed from well-watered and compacted haul road driving surfaces; however, substantial dust was emitted from the shoulders as a result of wind erosion and the movement of the haul trucks.

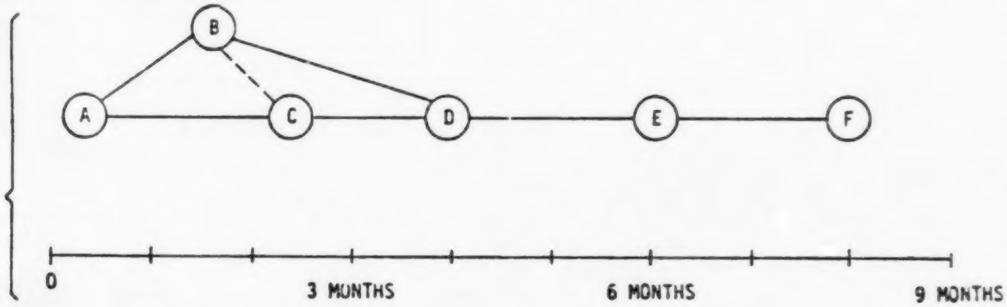
It is recommended that an investigation be conducted to assess the various control options available for stabilization of haul road shoulders. The study would involve field investigations of mines that currently employ shoulder stabilization practices and limited field testing to evaluate the most promising methods.

GUIDELINES FOR RECLAMATION TIME REQUIREMENTS

All surface mining causes considerable alteration of the land on which it occurs and the surrounding area as well. Reclamation basically consists of restoring these disturbed areas to their original contours, with subsequent revegetation to prevent erosion by wind and water. Although erosion losses are normally low except during wind storms, they occur continuously across the entire reclamation area.

The total wind erosion losses from a reclaimed area are directly proportional to the length of time required to establish protective vegetation on the surface. Most states in which surface mining predominates have regulations that require reclamation within a specified time period. However, the period required to completely reclaim an area varies considerably with site-specific factors such as climate, topography, soil type, and depth of cut. Information on required reclamation time as a function of these variables would provide a useful tool for reclamation agency officials.

It is recommended that a study be conducted to establish guidelines that prescribe reasonable reclamation schedules over ranges of site-specific variables. A survey of mining industry and government agency reclamation personnel would provide the major input for the study. The time required for phased reclamation operations would be presented in a format similar to that shown in Figure 18.



Activity designation

A-B Topsoil reconditioning
A-C Recontouring
B-D Fine grading
C-D Topsoil placement
D-E Seeding and mulching
E-F Irrigation as needed

Figure 18. Format for Scheduling Reclamation Operations.

FURTHER DEVELOPMENT OF EMISSION FACTORS AND EMISSION CHARACTERISTICS

Limited information is available on the emission factors and characteristics of individual mining activities. Table 6 presents a summary of emission factors for eleven different operations. Additional information is needed on six of these operations (listed below) to provide a concise and accurate emissions data on which to base comprehensive control methodology.

Overburden removal
Blasting
Haul roads
Crushing
Transfer and conveying
Reclamation

It is recommended that field sampling studies be conducted to substantiate emission data for the indicated operations. The upwind-downwind sampling procedure described in detail in Chapter 5 would be employed with some modification for short-term estimates. At least one of the downwind monitors would measure particle size fractionation (such as a hi vol with an Andersen cascade impactor) to provide a quantitative assessment of the respirable and suspended portions of the dust sample collected.

DEVELOPMENT OF METHODOLOGY FOR CONTROLLING EMISSIONS FROM OVERBURDEN REMOVAL

The limited data on emissions from overburden removal at surface coal mines and phosphate rock mines indicate that this operation is probably the most significant source of particulate emissions at these mines. Chapter 2 presents details on the relative significance of the eleven major fugitive dust producing operations at these mines. Unfortunately, with the possible exception of blasting, overburden removal is the most difficult source to control. The very nature of the operation--millions of tons of material being excavated and redistributed--for the most part precludes the use of conventional dust control methods. For instance, watering would place excessive demands on water supplies at most mines. This approach also has the potential of producing a water pollution problem (not to mention the problems associated with handling a wetted material). Nonetheless, the magnitude of overburden removal emissions warrants some type of control.

It is recommended that a study be conducted to develop control methodology for overburden removal. The initial effort would consist of an industry survey to ascertain if any viable control methods are currently practiced or are considered feasible. Subsequent field experiments would measure the efficiencies, costs, and residual effects associated with these control methods.

ASSESSMENT OF TECHNIQUES FOR CONTROLLING EMISSIONS FROM TAILINGS AREAS

Considerable experimenting has been done with chemical stabilization and revegetation to reduce dust emissions from tailings piles. Chemical stabilizers react with dry inactive tailings piles in the same manner they react with soils to form a wind-resistant crust or surface layer. Many of the chemicals tested to date have demonstrated long-term effectiveness. Revegetative stabilization alone is not a very cost-effective method of controlling tailings piles because of the limited nutrient support provided by most tailings materials and the excessive cost associated with topsoil covering; however, recently, several tailings piles have been planted successfully by use of a combination chemical-vegetative technique.

The Bureau of Mines (BOM) has funded several field studies to test chemical, vegetative, and combined chemical-vegetative techniques for stabilizing tailings piles. These research projects, however, have not included an ambient air monitoring program to quantitatively assess how effective these various methods are on air quality. A joint test program would permit evaluation of air quality impact and simultaneously provide additional emission data on this fugitive dust source. It is recommended that BOM-EPA integragency studies be undertaken, using test sites such as the expansive Kennecott Copper tailings pile west of Salt Lake City.

DEVELOPMENT OF SPECIFICATIONS FOR A RELATIVELY STANDARDIZED MONITORING NETWORK TO ASSESS THE IMPACT OF A MINE ON PARTICULATE AIR QUALITY

Limited data indicate that fugitive dust from mines, because of its size distribution and ground-level emission height, only has a detectable effect on ambient air quality within a 1/2-to 1-mile radius of the active mining operations. If this is correct, most mining operations would not significantly increase particulate concentrations off the mine property.

To gain more definitive information on the variation in measured particulate concentrations at various distances from mining areas and to provide a uniform procedure for identifying those mines with excessive impact on ambient levels, a standardized sampling network should be designed. Hopefully, this network design would be utilized in subsequent field studies so that data bases would be directly comparable. It could also be incorporated into regulations by reference, thus providing a potential enforcement tool (with further development) for control of a source whose compliance cannot be tested with stack emission rates.

The network specifications would include such parameters as the minimum number and type of samplers, placement relative to prevailing wind direction and distances from active mining operations, sampling frequency, duration of monitoring, and auxiliary information to be recorded on sampling days (e.g., meteorological data, process information). The network design should also be flexible enough to accommodate different mine and quarry configurations and available power access points.

It is anticipated that much of the project effort would be spent documenting in detail the rationale for each specification and summarizing the specifications in a concise form for subsequent distribution.

DEVELOPMENT OF A METHOD FOR ESTIMATING THE IMPACT OF A PROPOSED SURFACE COAL MINE ON PARTICULATE AIR QUALITY

Many new surface coal mines will be opened within the next 20 years as a result of increased energy demands. Because of the magnitude of these operations and/or their location on Federally-owned lands, most of these mines will need an Environmental Impact Statement or similar assessment prior to opening. To make the air quality analyses as meaningful as possible and minimize duplication of effort, a method for performing this analysis should be developed and established as the preferred procedure. Similar guidelines for environmental assessments of proposed highways have been published by the Federal Highway Administration (FHWA).

A standard method of assessing proposed mines should be developed in conjunction with the Federal Energy Administration (FEA) and other cognizant Federal agencies who would be responsible for the Environmental Impact Statements, such as the Interior Department's Bureau of Mines, Bureau of Land Management, or U.S. Geological Survey.

It is envisioned that the procedure would include three major parts:

- a method for converting expected mining activity rates into estimated emissions;
- a method for predicting the ambient pollutant concentrations resulting from the mining emissions;
- a method for establishing the predicted air quality in the area without the mining activity.

A major work area would involve coordination of project activity with several Federal agencies and incorporation of their ideas and comments into the final product.